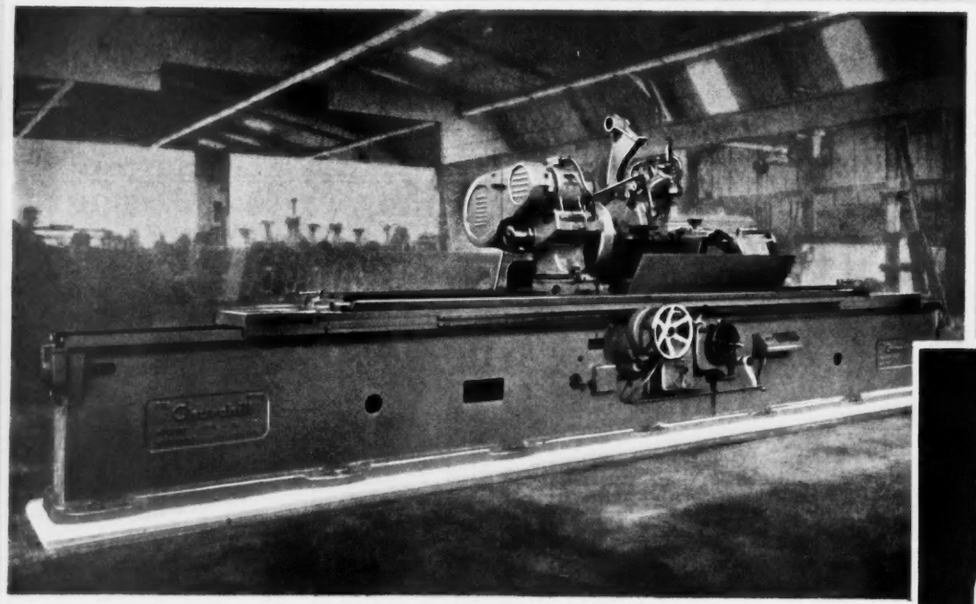
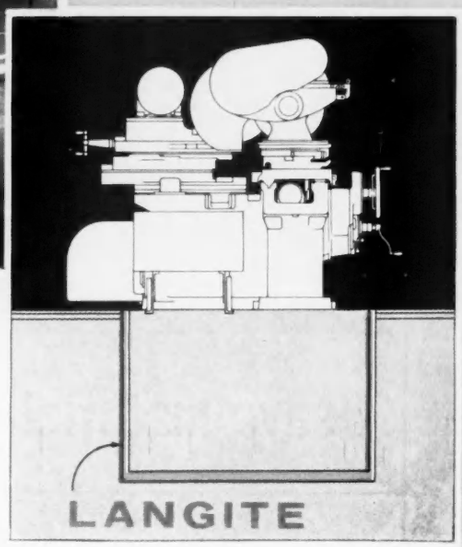
THE ENGINEER

NOVEMBER 27, 1959 | 28 ESSEX STREET, STRAND, LONDON, W.C.2 | TWO SHILLINGS





Isolating vibration with LANGITE

The vibration problems brought to us vary a good deal: often it is necessary to provide a resilient mounting to a machine so that its shocks or vibrations are not dispersed to cause annoyance of personnel or interference with other machines.

This Churchill Universal Grinding machine is installed at Shell Refining Co. Ltd., Shell Haven, and comes in another category. The object here is to protect the grinder from vibrations arising from other machines in the plant, so that its accuracy may be unimpaired.

The grinder is carefully levelled and set upon a massive reinforced concrete block, which in turn is cushioned underneath and at the sides on pads of resilient Langite 4V.

The result obtained by these simple means is wholly satisfactory.

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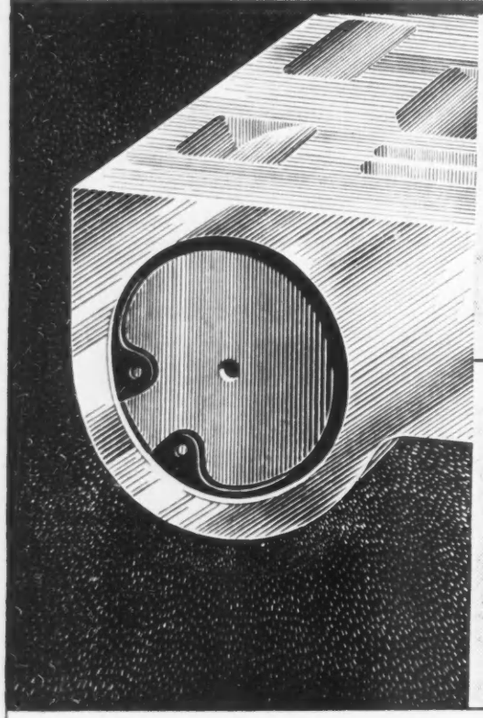
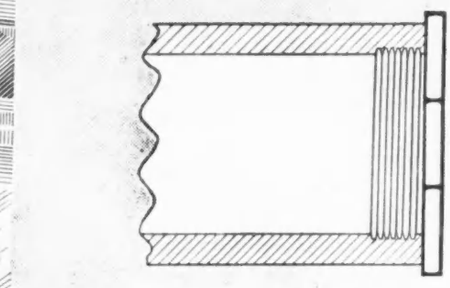
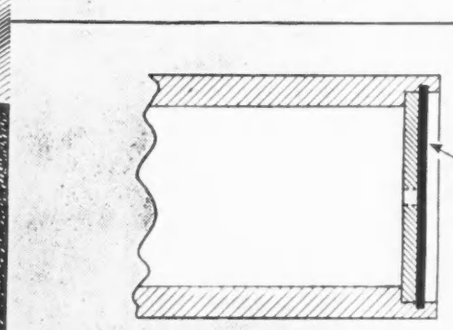




OLD WAY

This fluid seal involved internal threading of the tube, which was sealed with an expensive cap-nut. The assembly was laborious and spanners were needed.



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The tube is recessed and then simply grooved with the SALTER Grooving Tool. A Circlip is snapped into position and secures the fluid retaining plate with positive, vibration-free locking. When necessary the Circlip can be removed quickly and easily.

save material—reduce assembly time — cut costs

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No. 5418 **NOVEMBER 27, 1959** VOL. 208

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SUBSCRIPTIONS U.K. and ABROAD £5 10. 0. p.a., including postage (CANADA £5 5. 0.). Single copies 2s. each, plus 9d. postage. Also on sale at newsagents.

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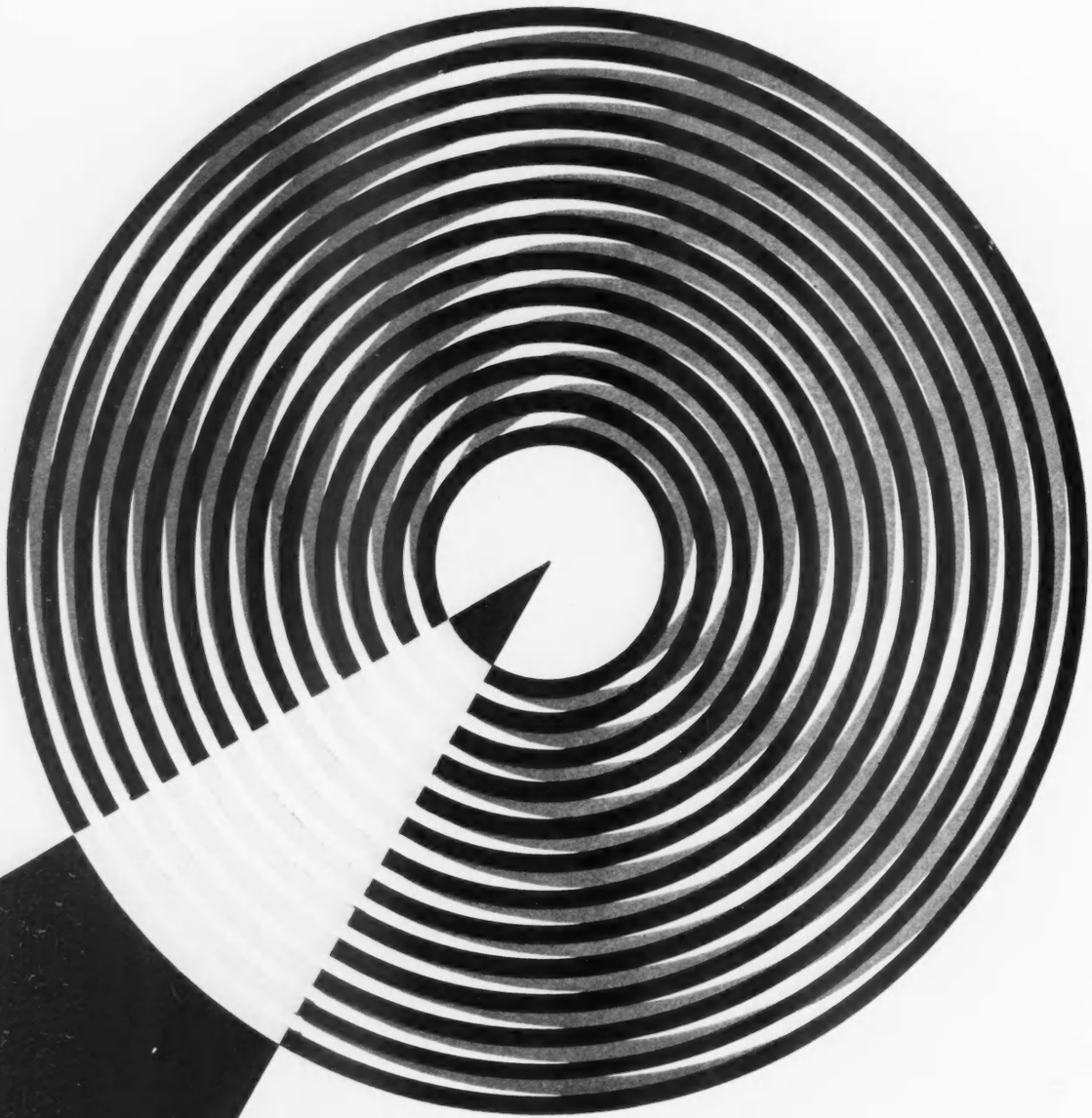

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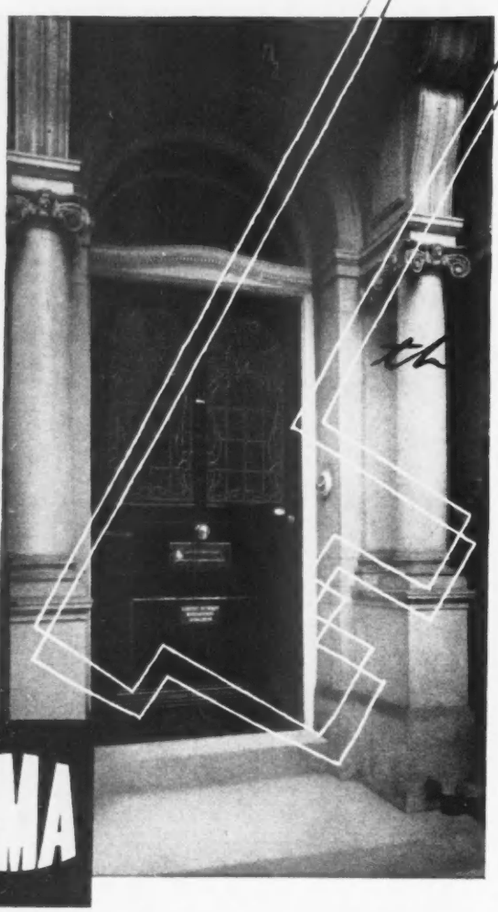

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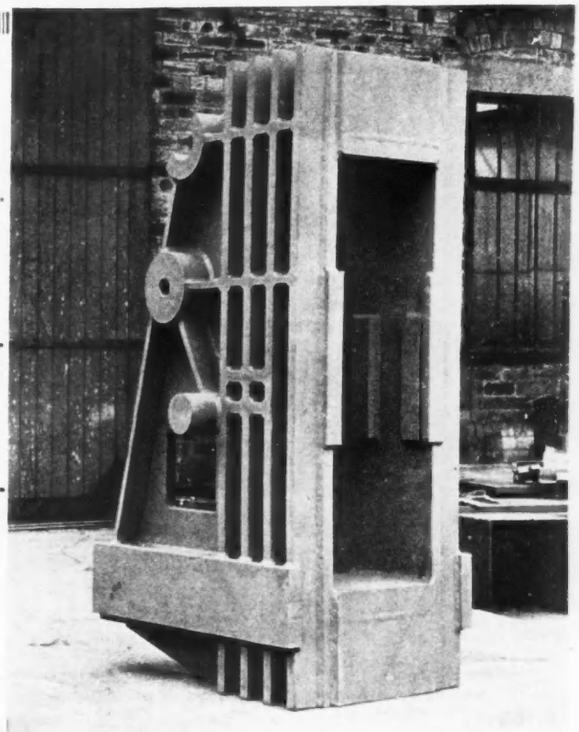

Front view of a fabricated steel frame for a special purpose 250 ton Knuckle Press.

Photograph by courtesy of the Glacier Metal Co. Ltd.

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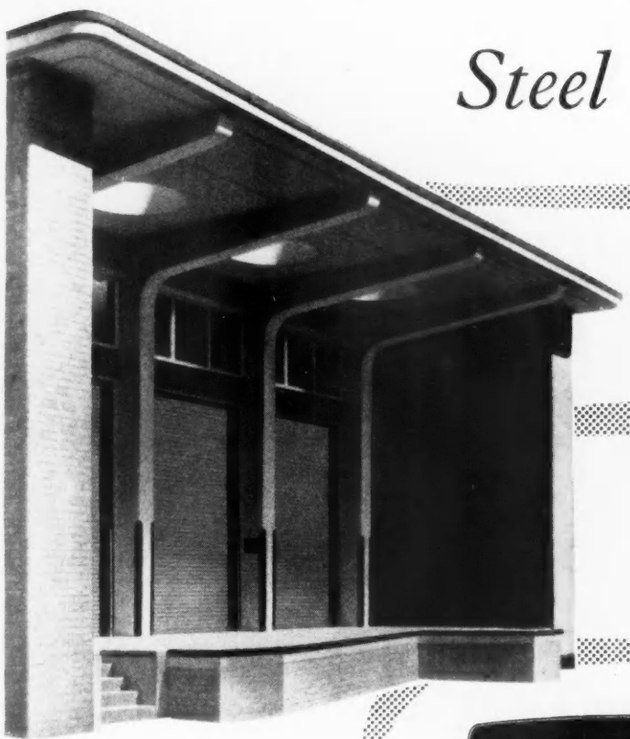

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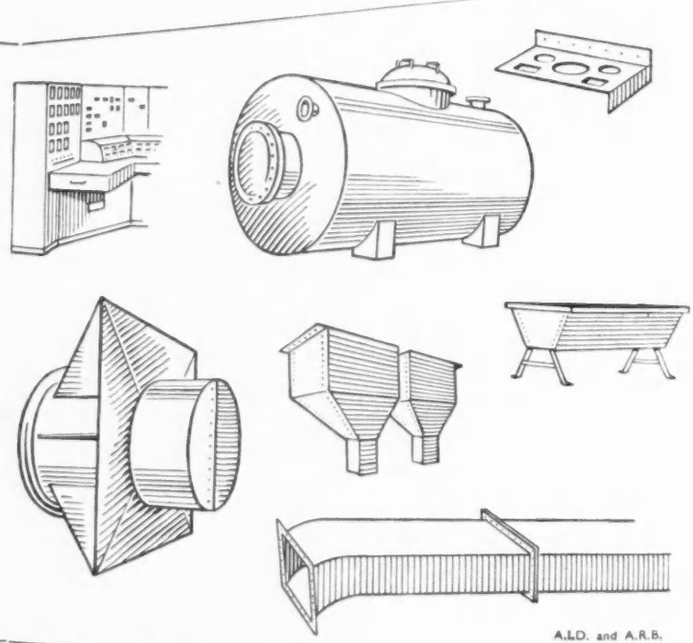

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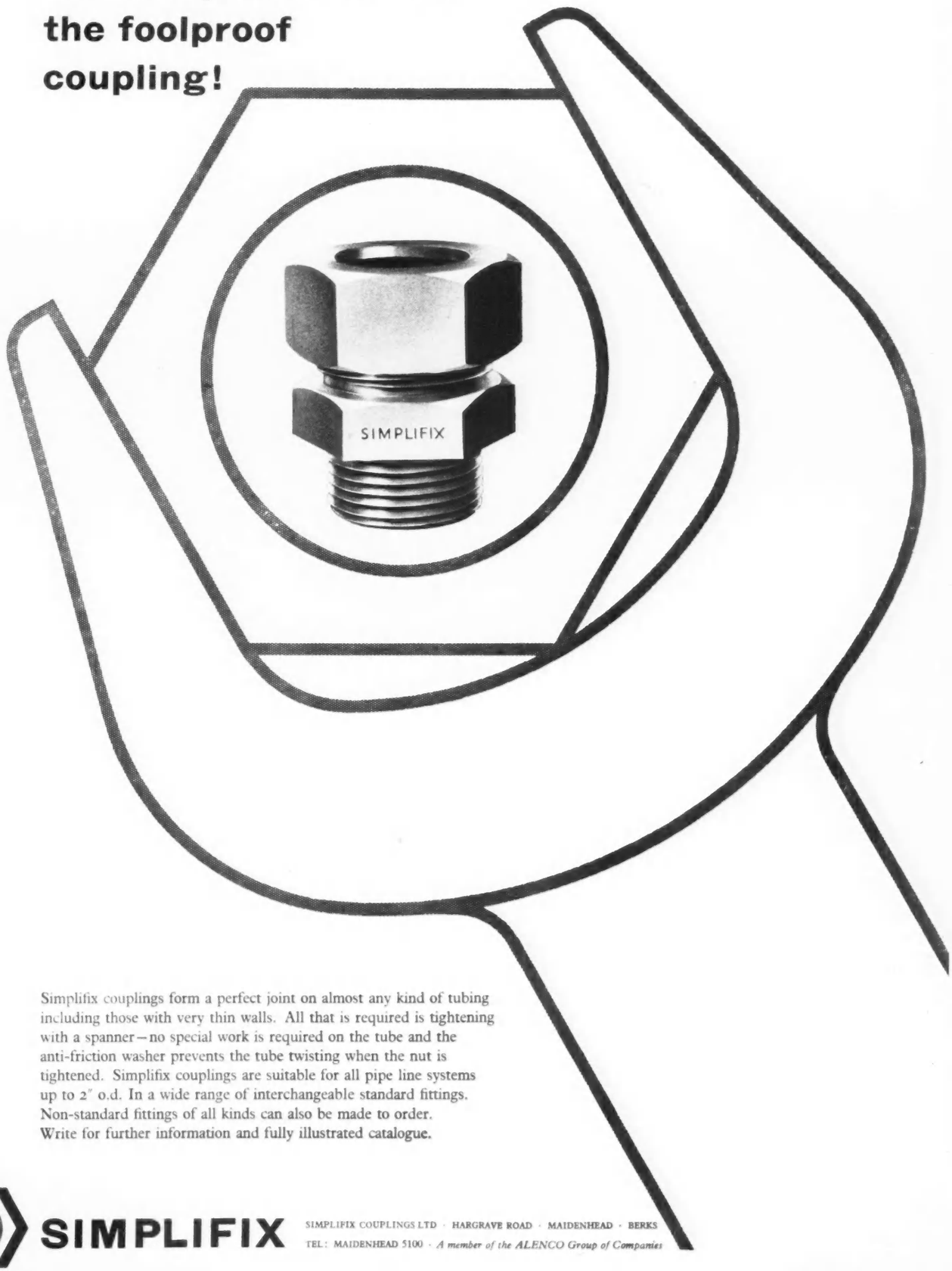

Simplifix couplings form a perfect joint on almost any kind of tubing including those with very thin walls. All that is required is tightening with a spanner—no special work is required on the tube and the anti-friction washer prevents the tube twisting when the nut is tightened. Simplifix couplings are suitable for all pipe line systems up to 2" o.d. In a wide range of interchangeable standard fittings. Non-standard fittings of all kinds can also be made to order. Write for further information and fully illustrated catalogue.

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The cone lock pipe stopper in position.

Pressure testing of open-ended steel pipes and pipe fittings is considerably simplified with the aid of cone lock pipe stoppers. These tools are designed to withstand test pressures of up to 2000 lbs./sq. in. and can be used successfully for any application where a simple, efficient and re-usable seal is required. For further details, ask for our leaflet "Cone Lock Pipe Stoppers."

The stopper is easily removed after testing by slackening the wing nut.

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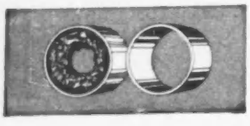

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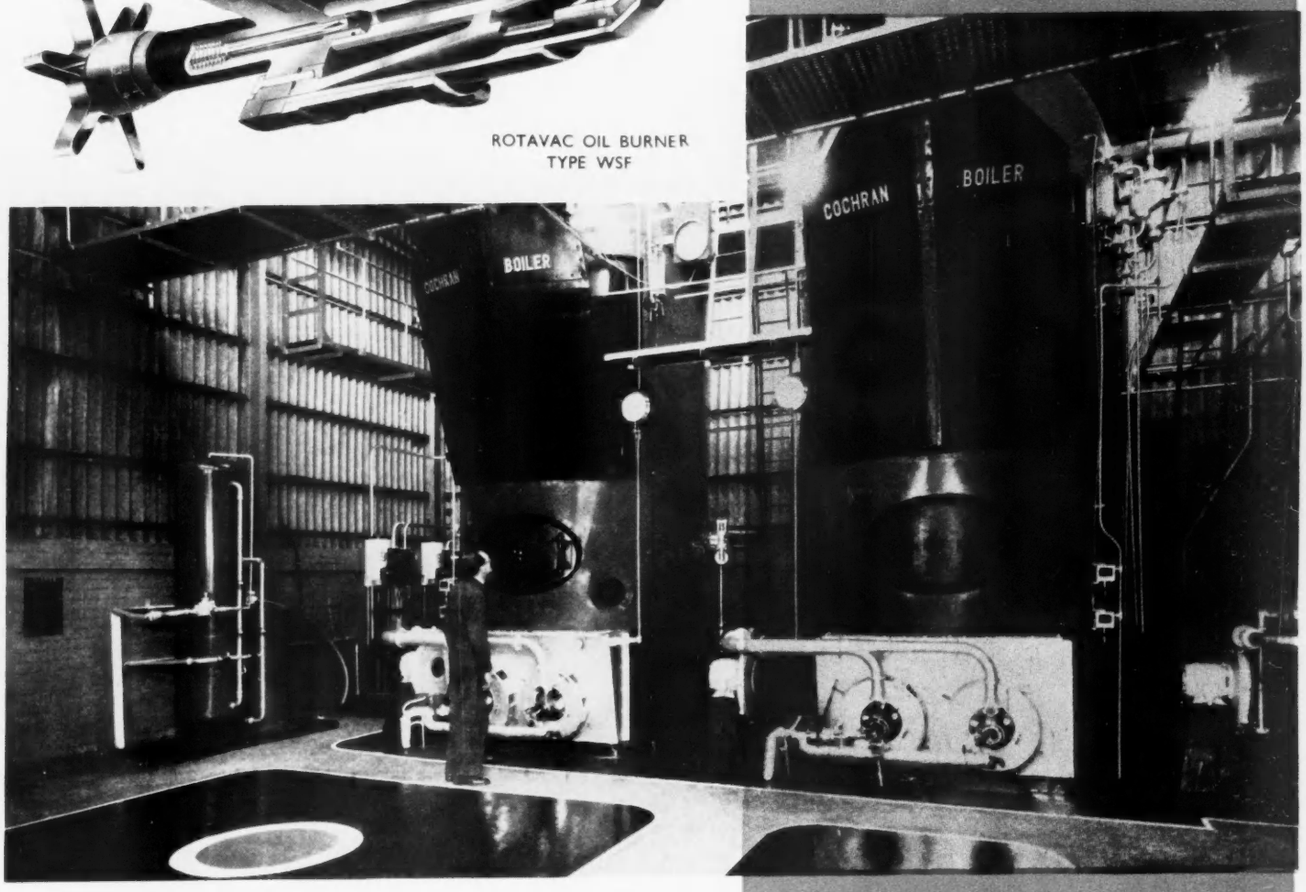

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MS

Silicone rubber insulated cables defy heat

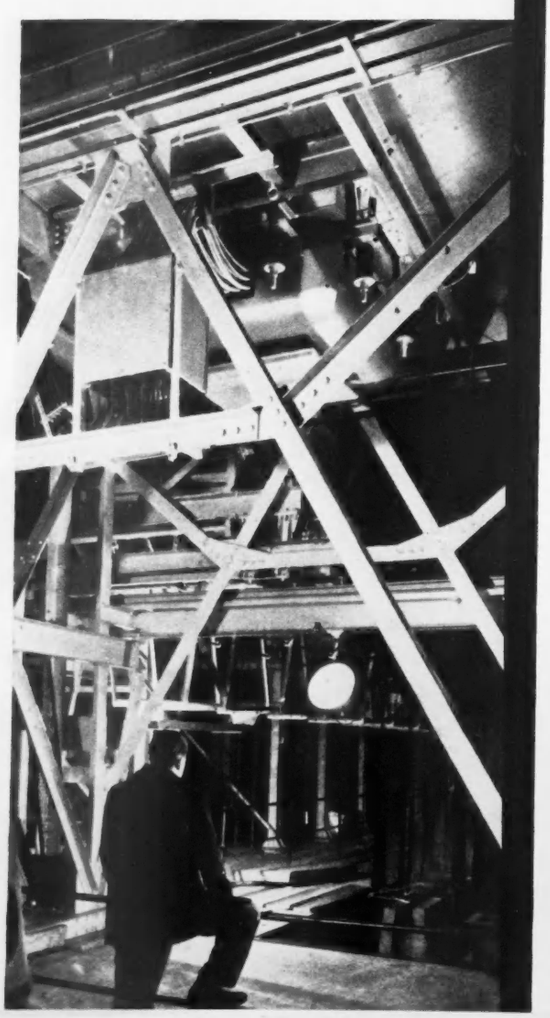
Silicone rubber insulated cables are used to supply the furnace heater batteries at the Rogerstone plant of Northern Aluminium Co Ltd and operate at an average temperature of 135°C. Each cable is 2200 .0076" single conductor tinned copper wire, silicone rubber insulated, asbestos roved, glass braided and silicone varnished — C.M.A. 660V grade.

The advantages of silicone rubber insulated cables are that they:

*Give continuous long term operation in ambient temperatures up to 200°C
*Will operate through and after fire
*Are resistant to steam, water and many chemicals
*Do not require any special terminating seals
*Have excellent resistance to electrical fatigue and corona discharge
*Are flexible at temperatures as low as -90°C

The silicone rubber insulated cables are installed above the quench tank (shown at the right) in which aluminium slabs are lowered after they have been taken from the furnace.

Photograph by courtesy of Northern Aluminium Co. Ltd.



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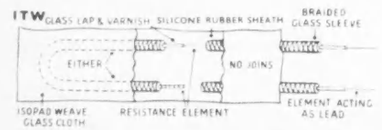
Silastomer* Silicone rubber works where other materials fail!

Isopad Ltd specify Silastomer silicone rubber for covering their flexible heating tapes designed for operation at temperatures of up to 200°C in moist conditions. And for good reason. Silastomer retains its flexibility and excellent dielectric properties over an extremely wide temperature range—from −100°C to +250°C.

No organic rubber can match this performance and that is why Silastomer is specified by Isopad and many other manufacturers for all types of equipment and appliances where reliability is essential—from seals in domestic irons to resilient diaphragms in valves.



Isotape tape ITW showing the heating elements covered with Silastomer silicone rubber. This weatherproofs the Isotape and makes it suitable for a temperature range of −100°C to 222°C.

*Silastomer is a registered trade mark of Midland Silicones Ltd.

Isotapes being fitted to bitumen feed pipes

(Photograph by courtesy of Isopad Ltd)

MS

Silicone greases remain serviceable from −70°C to +230°C

London Transport were experiencing considerable difficulty during cold weather due to the sticking of unloader valves on the compressors of their Green Line buses. An MS silicone grease solved the problem. Because of their outstanding resistance to extremes of temperature, MS silicone greases remain serviceable over a far wider temperature range than organic lubricants, thus providing reliability in operation and a reduction in maintenance costs. An MS silicone grease or lubricant may offer the most practical and economical solution to your most difficult lubricating problem.

The photograph shows the unloader valve fitted to Green Line buses. Courtesy of London Transport Executive.

Write for full information about these and the many other silicone products with applications in the engineering industry including release agents, damping and hydraulic fluids, heat-resistant paint resins, lubricants and electrical insulants.

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MS

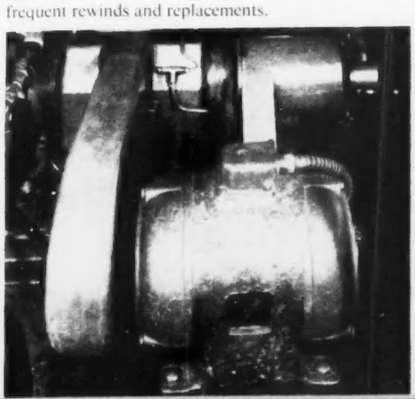
Silicone-insulated motors withstand years of continual 'plugging'

The photograph shows a silicone-insulated motor operating at the Stonehouse Works of Hoffman, Gloucester Ltd, who have kindly provided us with the following information—"We have a bank of 12 machines, each being driven by a 2 h.p. 1425 r.p.m. motor and as the motors have burnt out they have been rewound with silicone insulation, by British Electrical Repairs Ltd, and this has proved very satisfactory over the past 2-3 years.

"These motors are working in unusual conditions, as the following description of their working cycle shows, and they stand up to the work very well indeed.

"A complete operation takes 12 seconds then the machine is operated to reload which takes 2 seconds. To decelerate rapidly to the stop position for loading the operator presses the stop button followed by 'plugging' (pressing the reverse button). This is drastic treatment when continued all day and speaks well for the rewound motors".

This is a typical example of how MS silicone insulation increases the life and reliability of hard-working motors . . . saves money by reducing the need for frequent rewinds and replacements.



MS

Silicone fluids speed production at Mullards

An MS silicone fluid is used in the SPEEDIVAC* vacuum diffusion pumps which serve each plant of this rotary machine for producing Radiant Screen television tubes at the Mullard Television Tube plant at Simonstone. Because of the excellent heat stability and oxidation resistance of the silicone fluids, cooling of the pumps before releasing the vacuum is not necessary. Rapid cycling is therefore possible resulting in more efficient production.

*Trade name of Edwards High Vacuum Ltd.

Because of their versatility MS silicone fluids overcome many of the limitations of organic fluids and open the way to improvements in the design of equipment and in production techniques. Advantages include:

* Serviceable temperature range from −100° to 450° F.
* Available in viscosities from 0.65 to 1,000,000 centistokes
* High flash points
* Low vapour pressure
* Excellent oxidation resistance
* Low coefficient of expansion
* High degree of compressibility

Write for Silicone Notes GE1 which details many of the applications of MS fluids.

Photograph by courtesy of Mullard Limited.

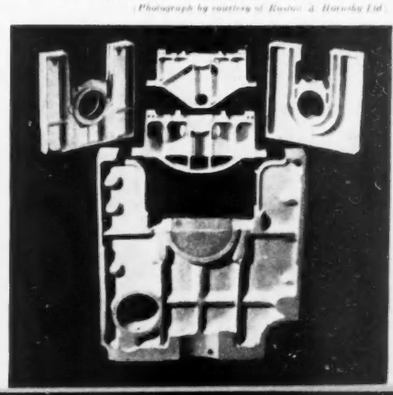
MS

Cold-Cure Silastomer* aids diesel design research

Cold-Cure Silastomer—the silicone rubber that needs no heat to cure—is used for making scale models of diesel engine components to enable their behaviour to be studied under different simulated loads.
Wooden moulds are made, assembled and painted with a release agent and the Cold-Cure Silastomer is poured in and left to set. No special equipment is needed and the models are ready for use in about 24 hours after casting at room temperature.
Cold-Cure Silastomer is remarkably versatile and opens up new fields for designers. The addition of a catalyst is all that is required to cure at room temperature and the material possesses the excellent dielectric properties, heat endurance and high thermal conductivity associated with silicone rubbers. Cold-Cure Silastomer can be used by unskilled operators to fill voids round lead wires of coils and motors, for impregnating coils, and for other similar sealing or potting applications. It can also be used for making flexible moulds in which epoxide resins are cast.
Write for a sample—on your company letterhead please—of either Cold-Cure Silastomer 9160 or 9161. The former has a spreadable consistency and the latter is suitable for dipping. Silicone Notes K28 is also available listing the properties and applications.

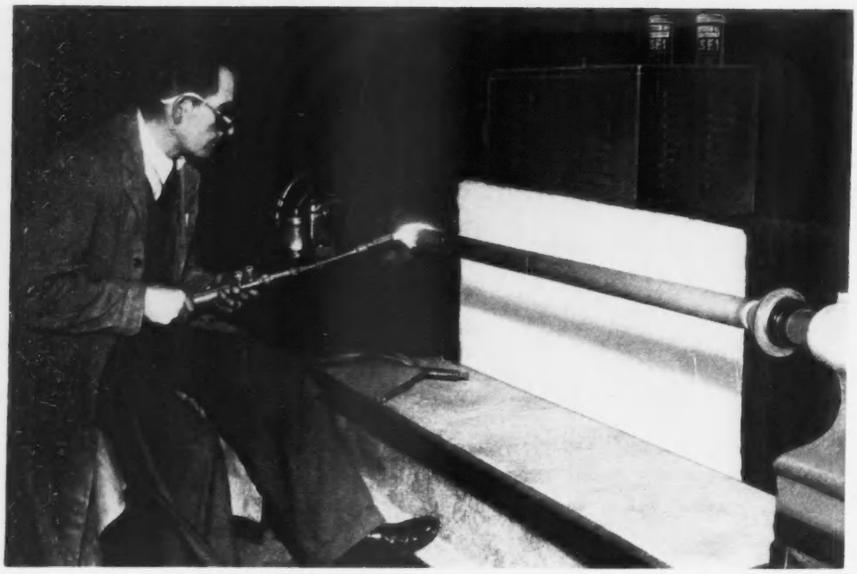
*Silastomer is a registered trade mark of Midland Silicones Ltd.

Photograph by courtesy of Rustons & Hornsby Ltd.



"STELLITE" SPRAY FUSED ALLOYS HAVE MANY ADVANTAGES

- *FASTER HARDFACING*
- *WIDER APPLICATIONS*
- *MORE ECONOMY*
- *LESS SKILL REQUIRED*



Operator fusing a pump ram.
(Photograph by permission of Burtonwood Engineering.)

Deloro Stellite have developed the spray fusing method of applying cobalt base alloys. This means that all the abrasion, corrosion and heat resisting properties of these alloys can now be used to advantage by means of this modern process.

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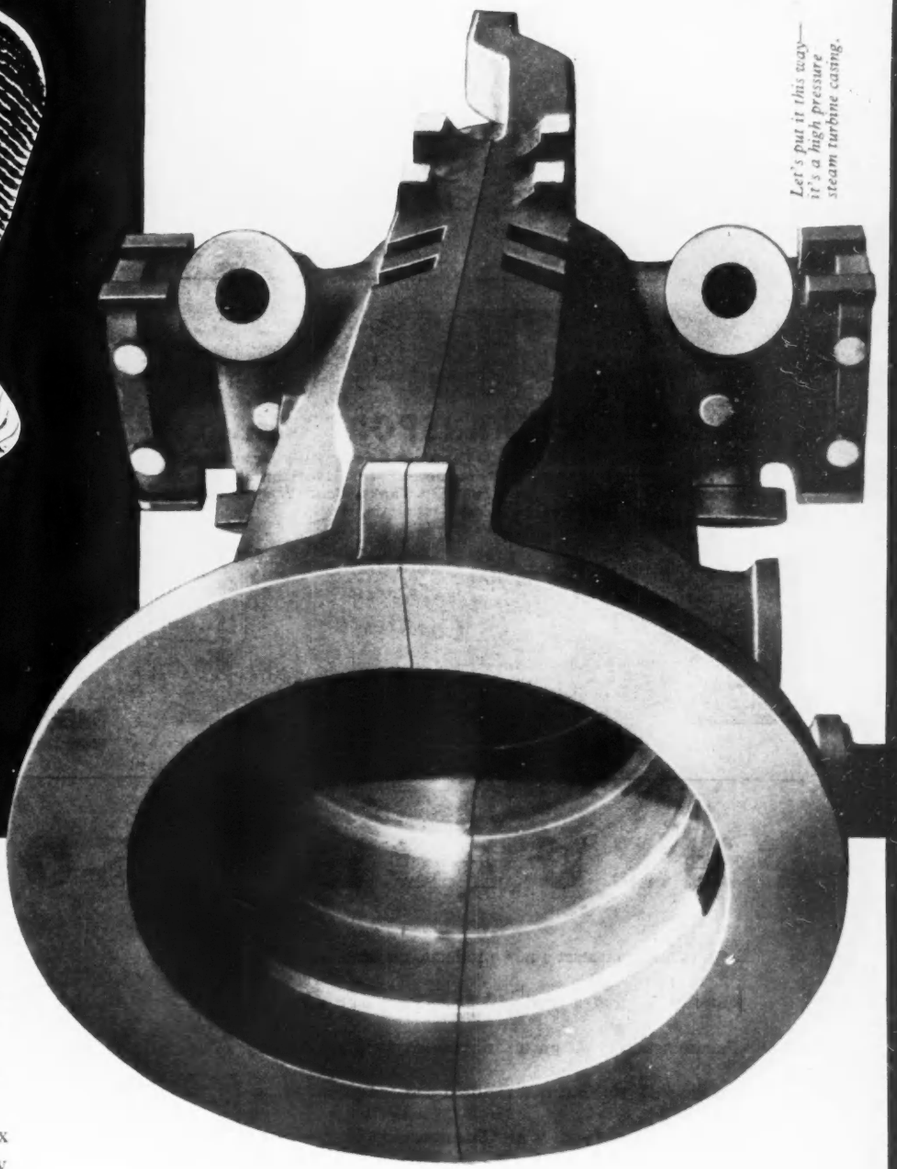
Brown Magic



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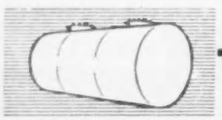

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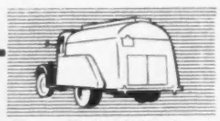

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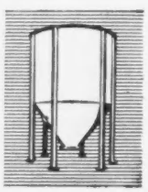

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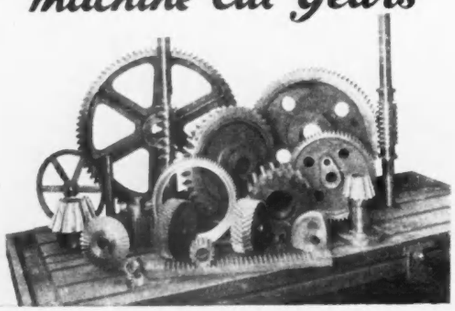

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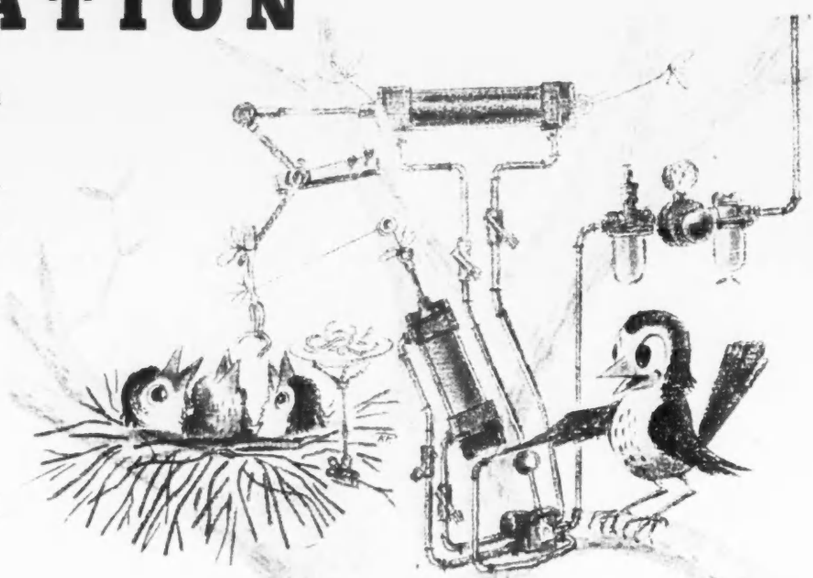

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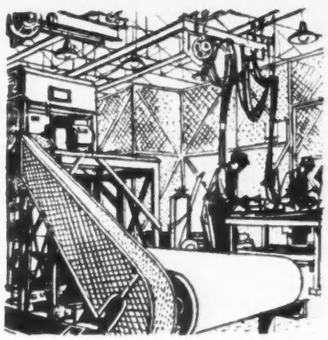

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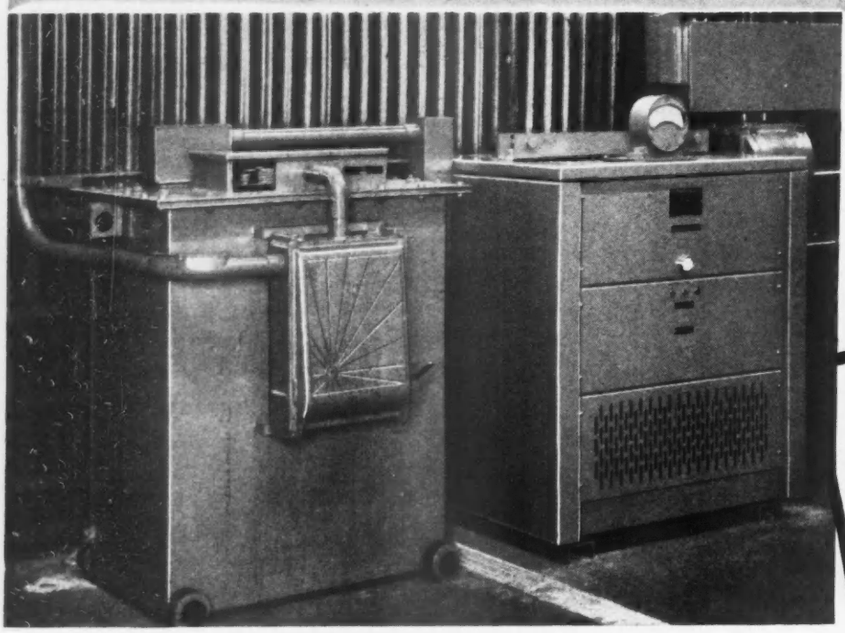

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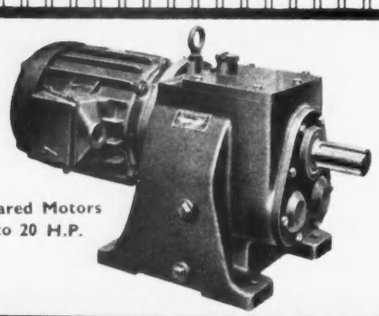

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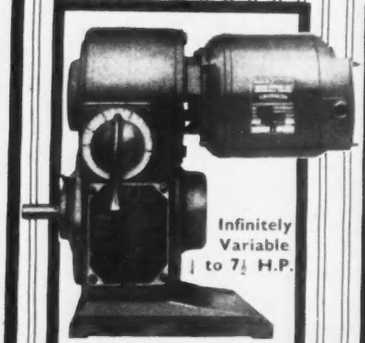

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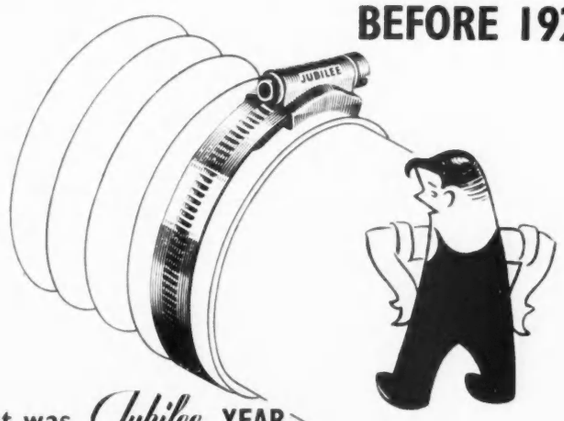

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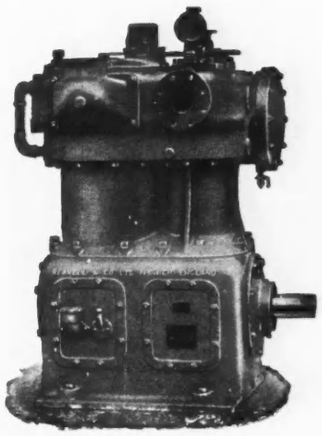

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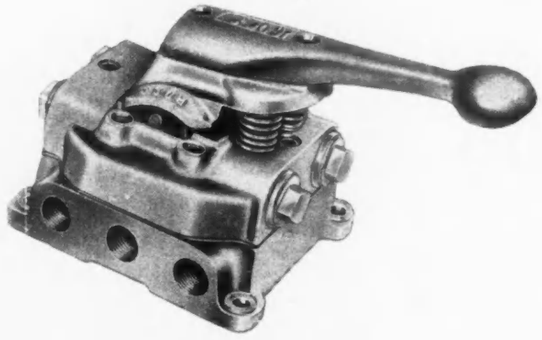

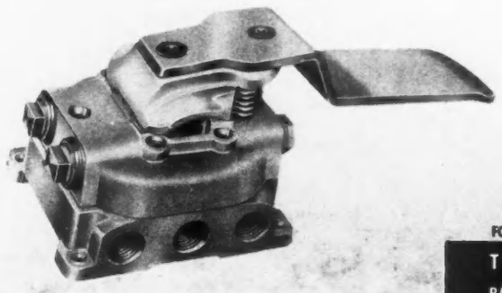

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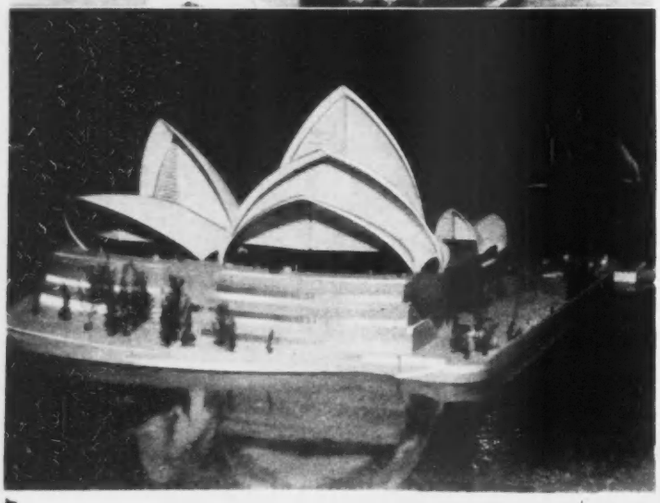
Type WR 120 operating "BROOMWADE" Pneumatic tools on site.

General view showing clearance for site.



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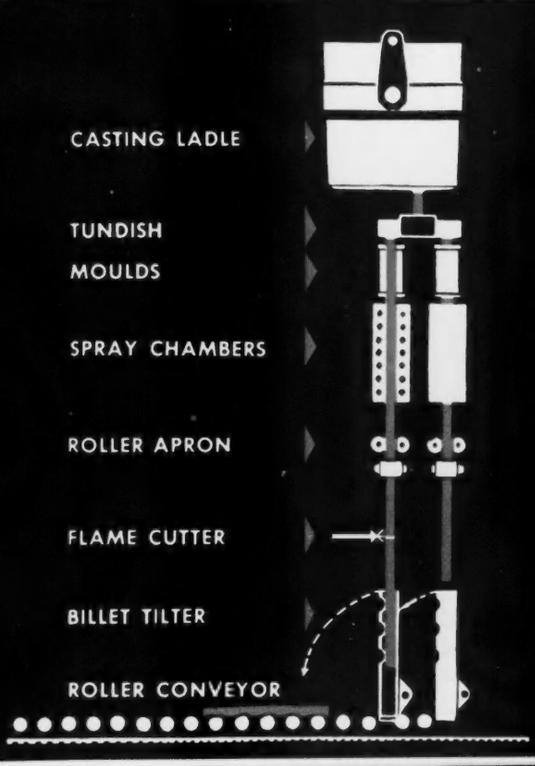

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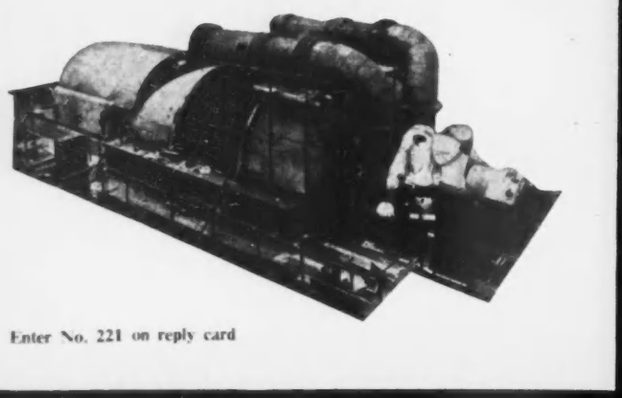

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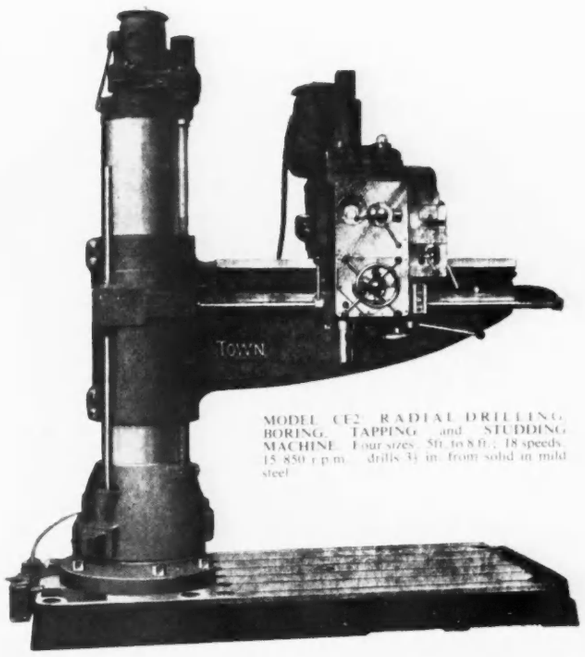

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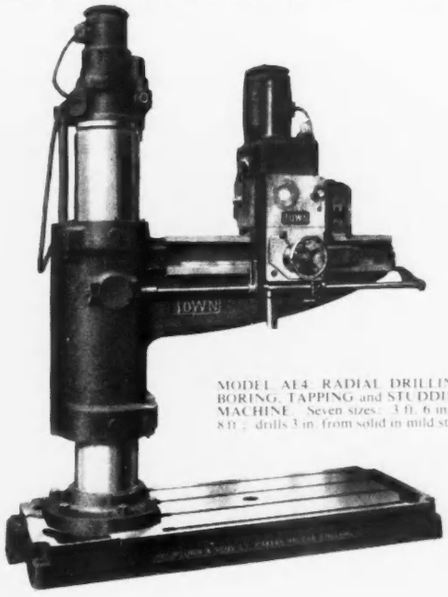

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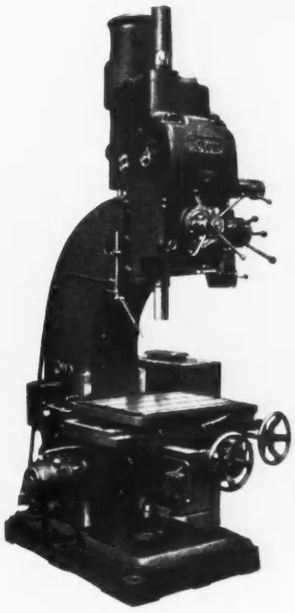

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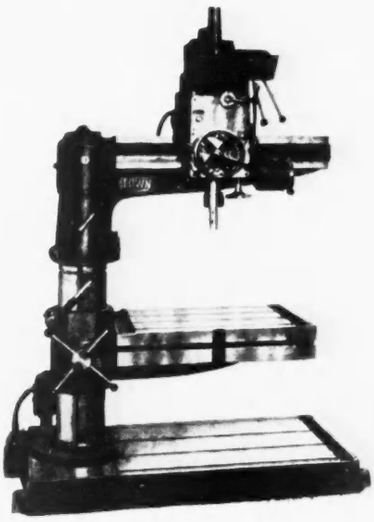
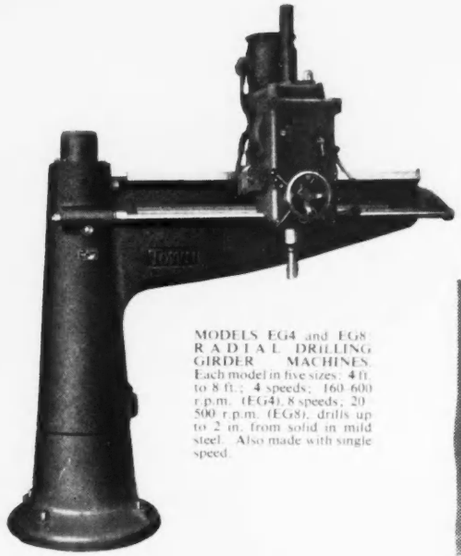


MODEL AE5 RADIAL DRILLING, TAPPING and STUDDING MACHINE. 42 in.; drills 1¾ in. from solid in mild steel or 1¾ in. in cast iron.



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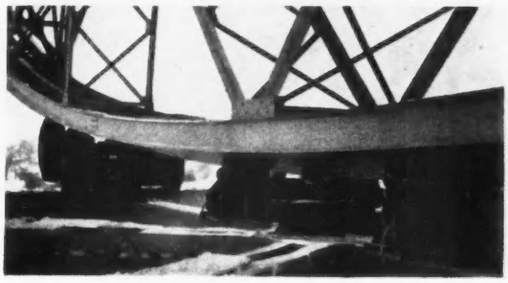

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The Heatrae "Express" marks a big jump forward in Electric Water Heater design.
The economy eye glows when the current is on and is extinguished when the correct temperature is reached.

The special dispenser outlet ensures smooth even flow and instant cut-off when closing the valve.
Available in loadings of 3kW or 2kW at 230/250 volts, or 200/220 volts, A.C. only.
Finish cream or white.
Price :—£10 12s. 6d. plus P. Tax :—£2 1s. 5d.
Full details on Leaflet No. 92 sent on request.

HEATRAE LIMITED · NORWICH

Telephone: NORWICH 25131 (Private Exchange) **Telegrams: HEATRAE · NORWICH**

Manufacturers of Electric Water Heaters, Oil Heaters, Immersion Heaters, Urns, Towel Rails, Airing Cupboard Heaters, Electric Fires, Flameproof Heating Apparatus, Food Trolleys, Warming Plates, Air Heaters and Steam Heated Oil Heaters.

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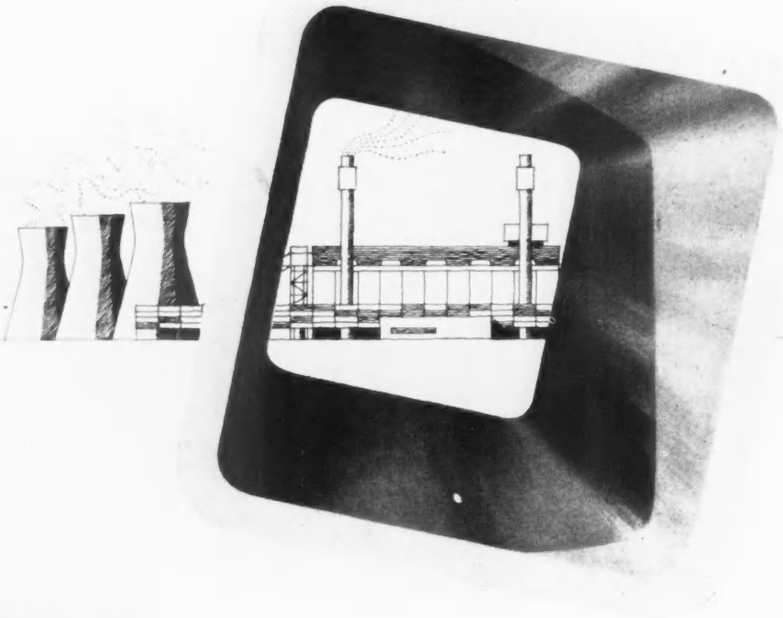

WHAT'S IN A TUBE?

In every Chesterfield tube there is a lot of experience that doesn't show on the surface. Whether we are drawing a header for the boiler of a power station or turning out a miniature gas bottle to inflate a life-jacket, we make use of manufacturing techniques and individual skills that have taken anything up to 50 years to perfect. There is no substitute for the experience that goes into ***chesterfield tubes.***

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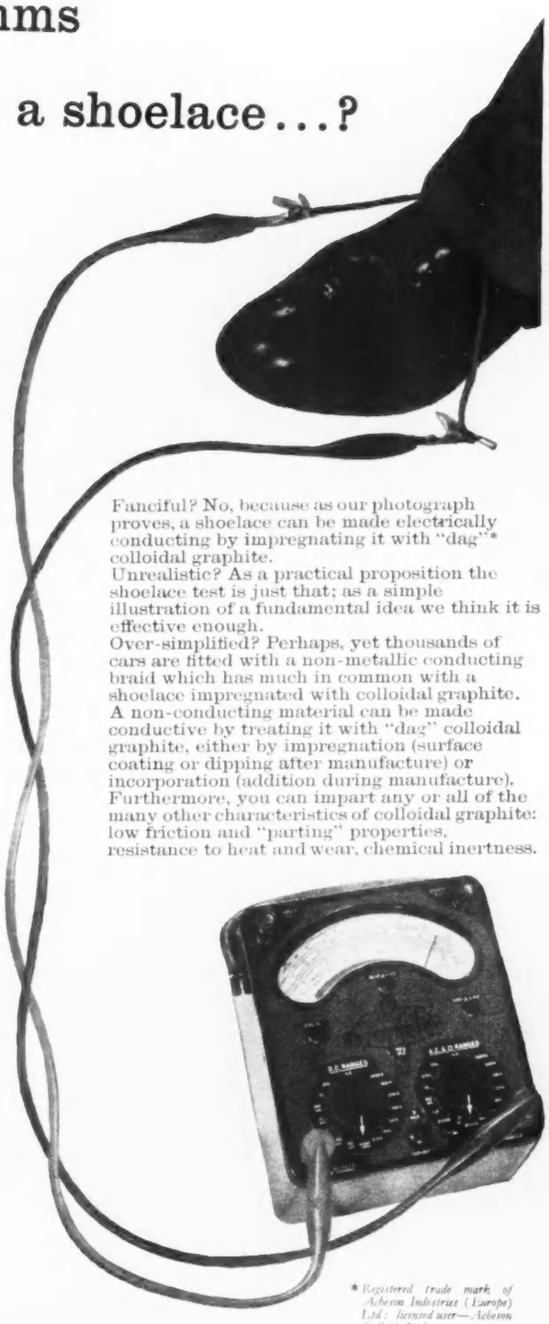
how many ohms in a shoelace...?



Fanciful? No, because as our photograph proves, a shoelace can be made electrically conducting by impregnating it with "dag"* colloidal graphite.
Unrealistic? As a practical proposition the shoelace test is just that; as a simple illustration of a fundamental idea we think it is effective enough.
Over-simplified? Perhaps, yet thousands of cars are fitted with a non-metallic conducting braid which has much in common with a shoelace impregnated with colloidal graphite.
A non-conducting material can be made conductive by treating it with "dag" colloidal graphite, either by impregnation (surface coating or dipping after manufacture) or incorporation (addition during manufacture). Furthermore, you can impart any or all of the many other characteristics of colloidal graphite: low friction and "parting" properties, resistance to heat and wear, chemical inertness.

*Registered trade mark of Acheson Industries (Europe) Ltd.: licensed user—Acheson Colloids Ltd.

If your problem is basically how to make plastics, natural or synthetic fibres, leather, cloth, paper or wood electrically conducting, then you should get in touch with us.

Acheson Colloids
LIMITED
(a subsidiary of Acheson Industries (Europe) Limited)
P.O. BOX 12 · PRINCE ROCK · PLYMOUTH · DEVON

Manufacturers of dispersions of colloidal graphite, molybdenum disulphide, silver, glass, vermiculite in suitable carrier liquids including oil, water, white spirit, alcohol and toluene.

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A TOUCH OF THE BUTTON

and up comes the water

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CLEVELAND
THE CLEVELAND BRIDGE AND ENGINEERING COMPANY, LTD.

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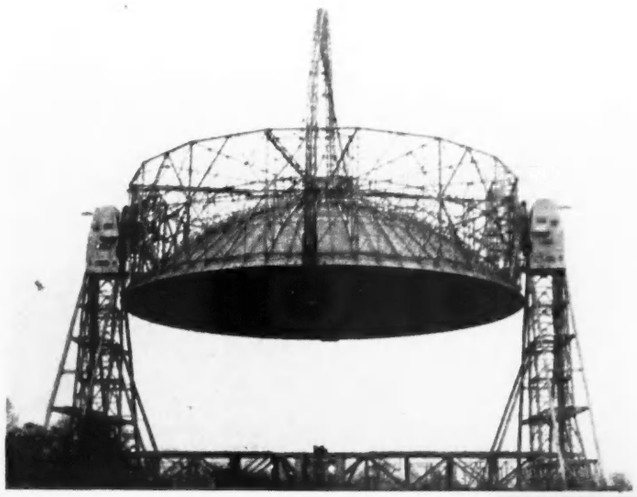

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In addition some 40 Pedestals in sizes from 4½in. to 10in. bore are used for the Bogie drives and Reflector actuation.

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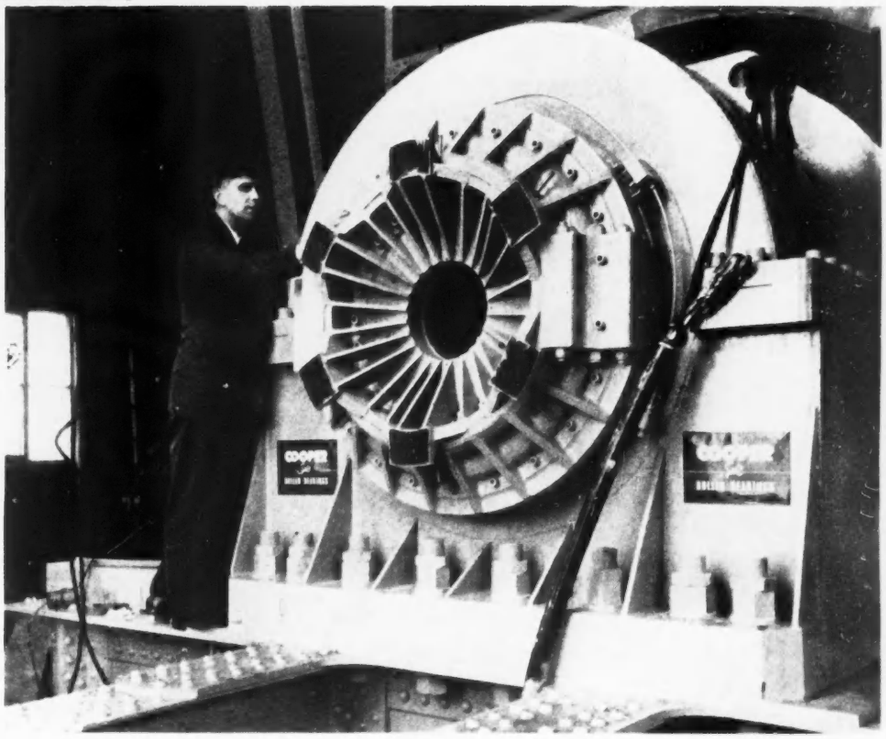

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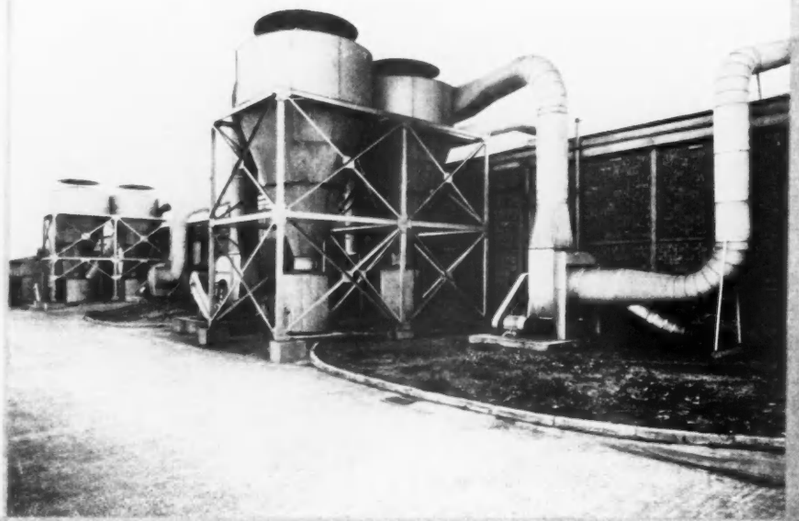

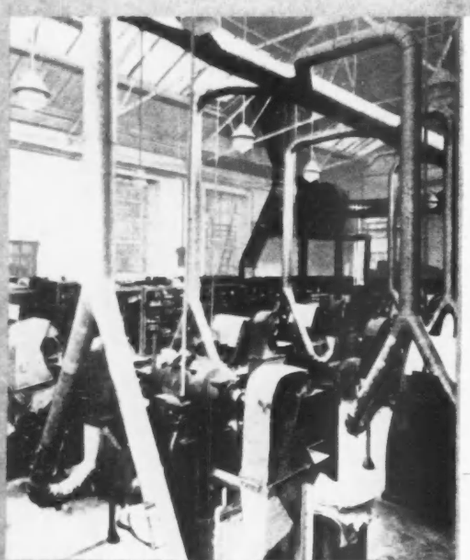

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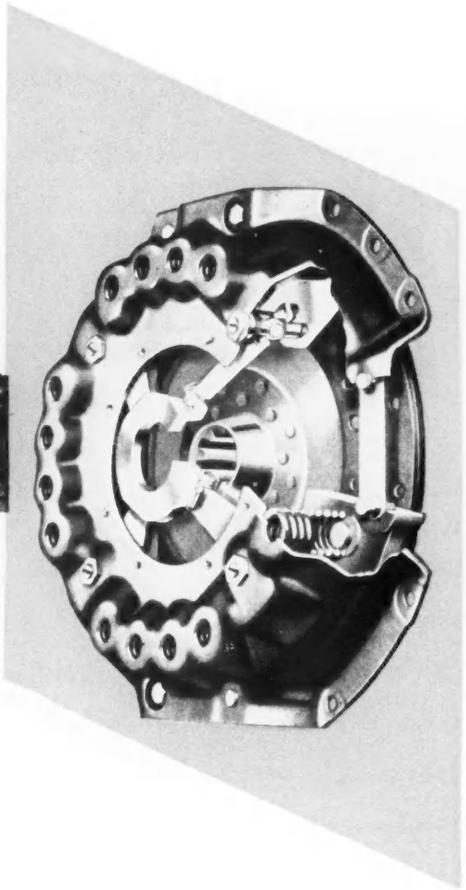

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The 13" strap-drive Borg & Beck clutch, as illustrated, is giving excellent service in the main transmission of many famous medium-range loaders. The drive to the moving pressure plate, through tangential straps, eliminates sliding friction, cuts out wear, and thereby maintains efficient centralization and consequently running balance.

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Borg & Beck clutches are fitted to the following:

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BORG & BECK CLUTCHES

REGD. TRADE MARK BORG & BECK

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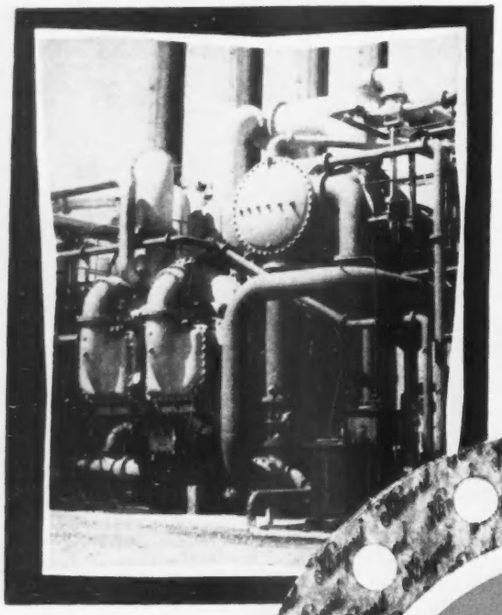
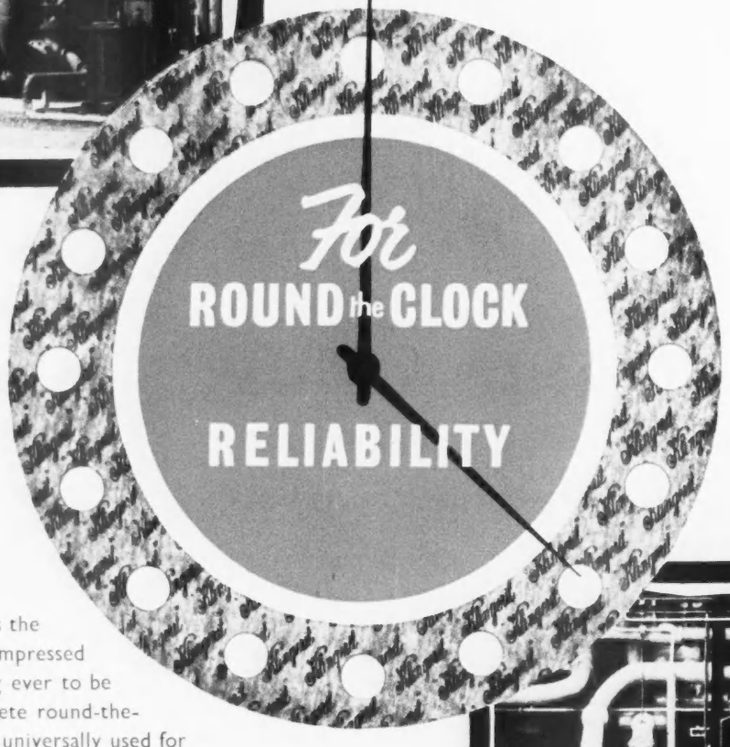


Klingerit JOINTING



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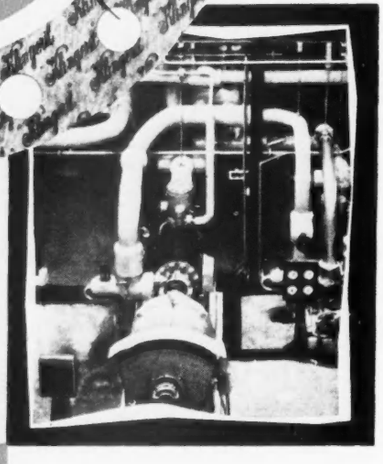

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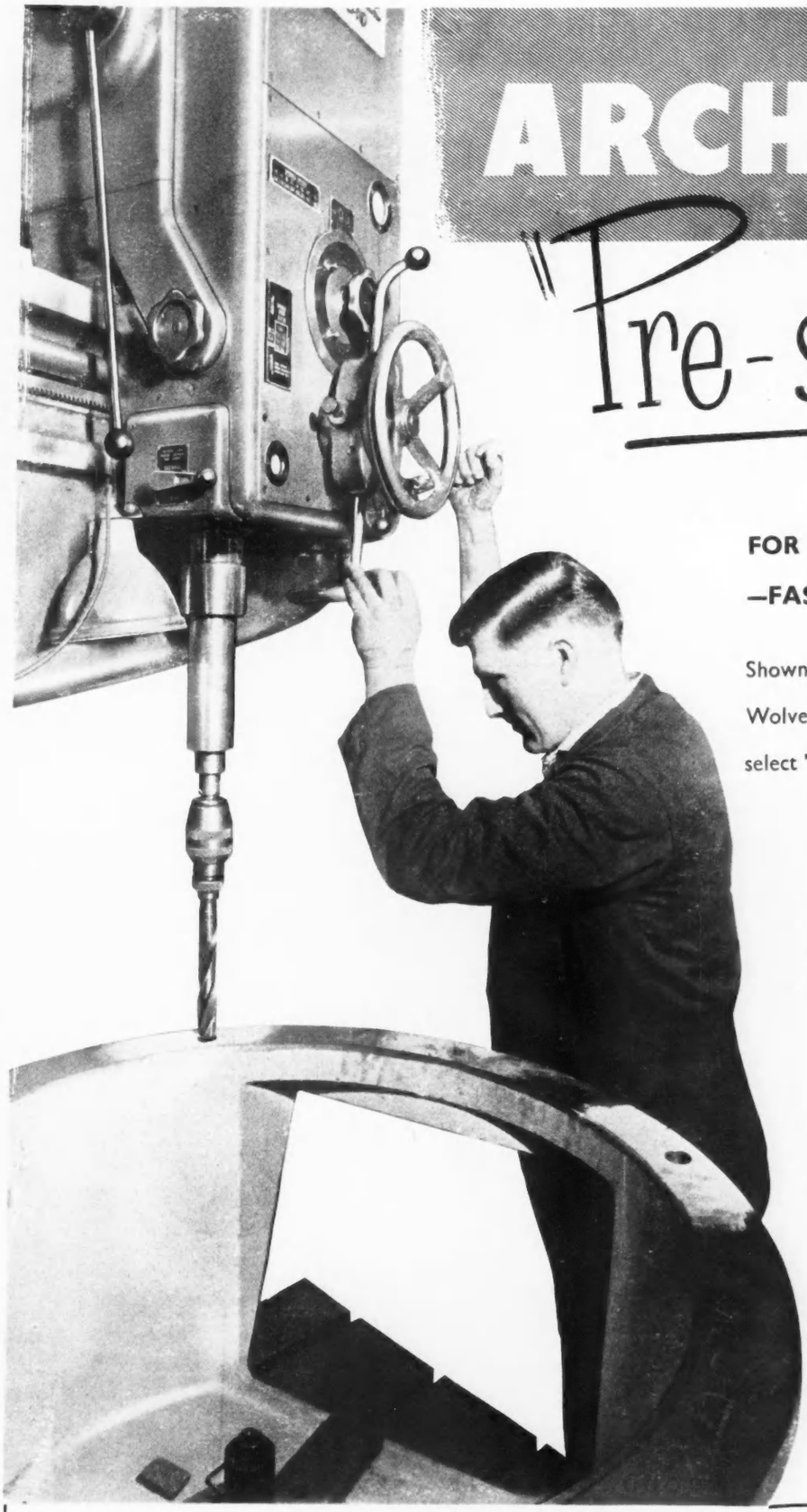

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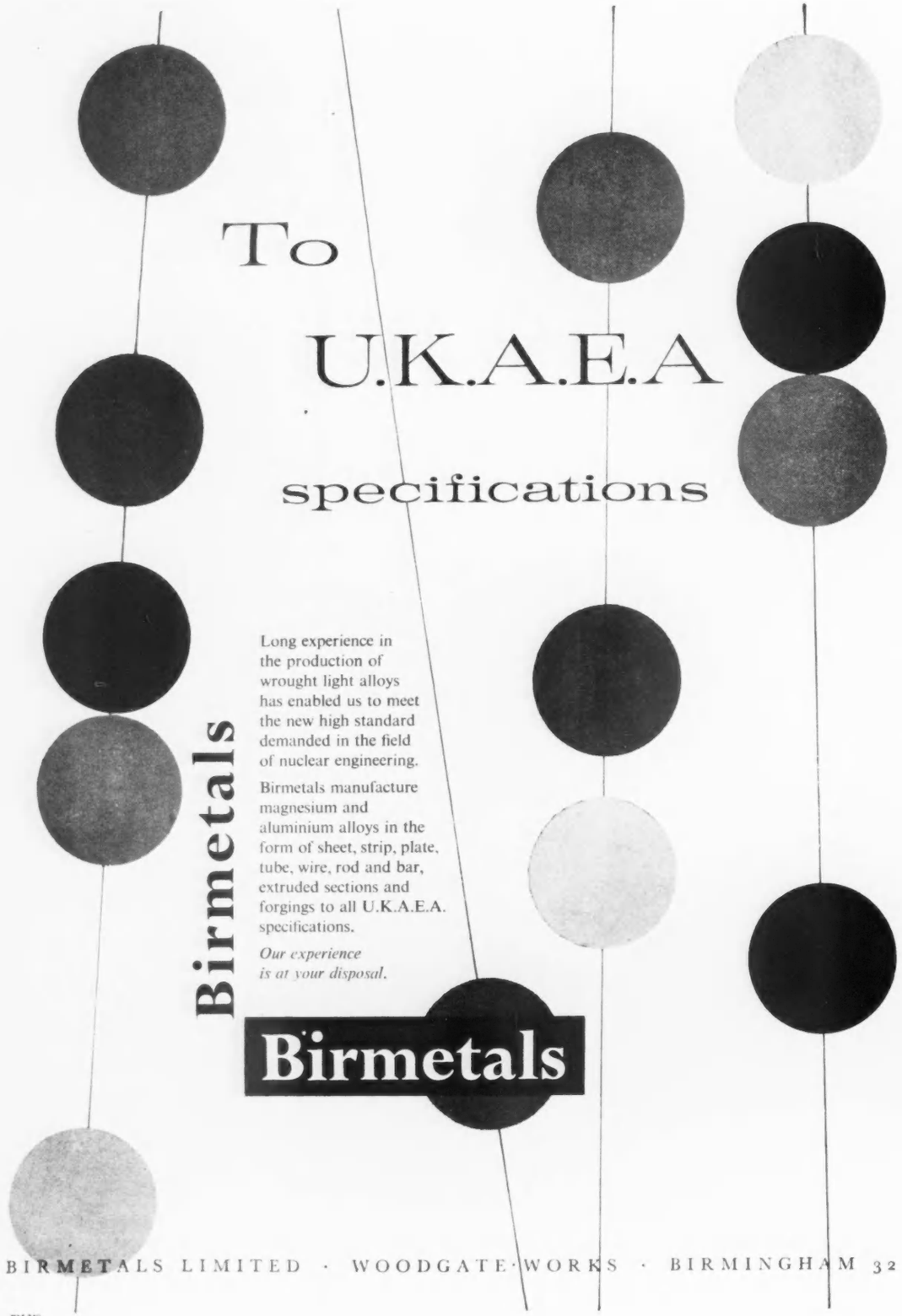
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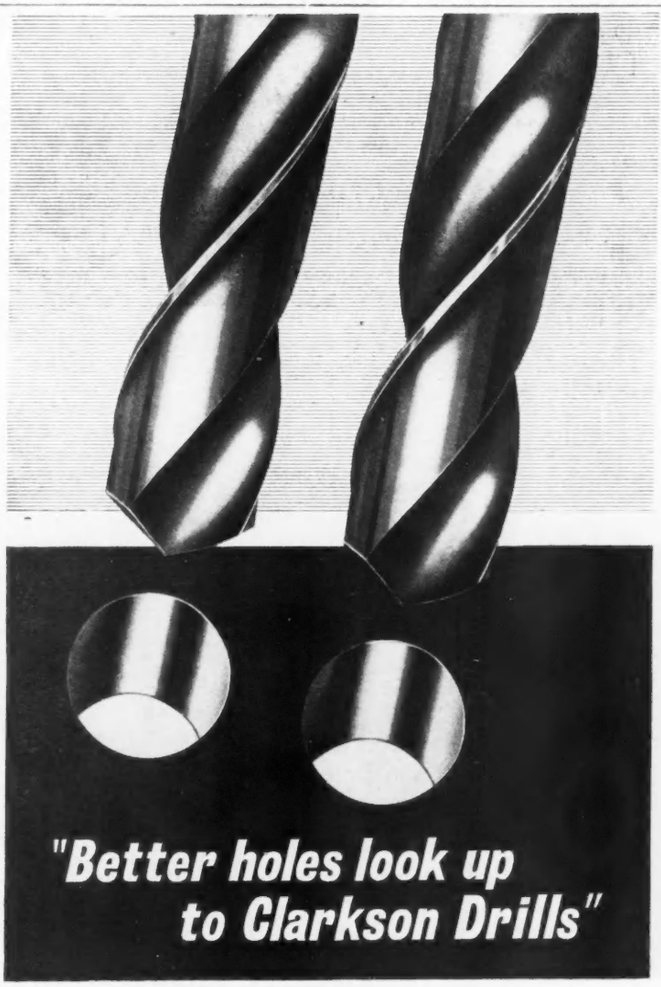

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The illustration shows a 1" eccentric-type self-adjusting joint. This forms the crank-pin and big-end bearing of a crank operating the cutter bar of a mower, at many hundreds of strokes a minute.

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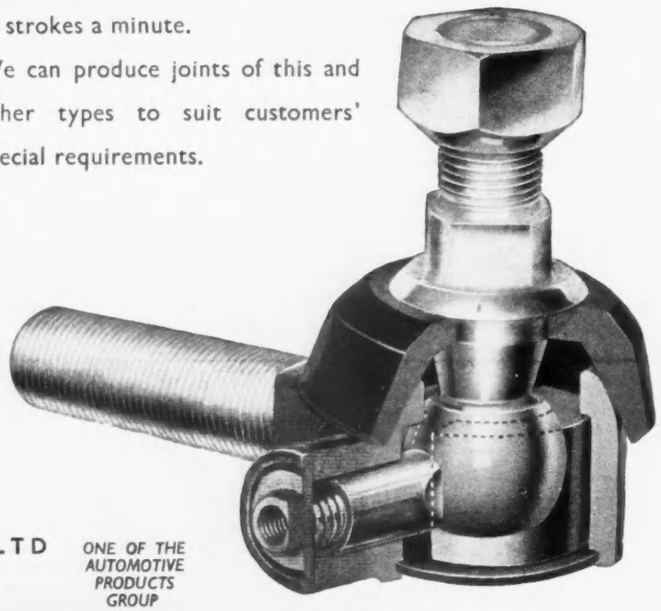

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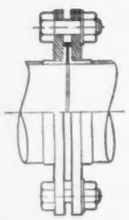

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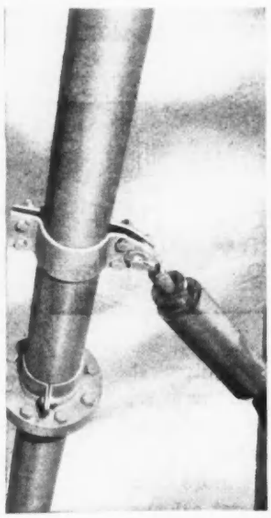
"Bracing" weather for pipework



Shocks and vibration give rise to high stresses in pipework, with possible subsequent damage to piping and associated equipment. Pipework on board ship subjected to vibration or in land installations exposed to high winds, is particularly prone to these hazards.

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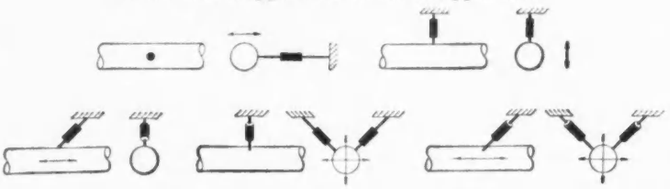
Sketches of suggested methods of application



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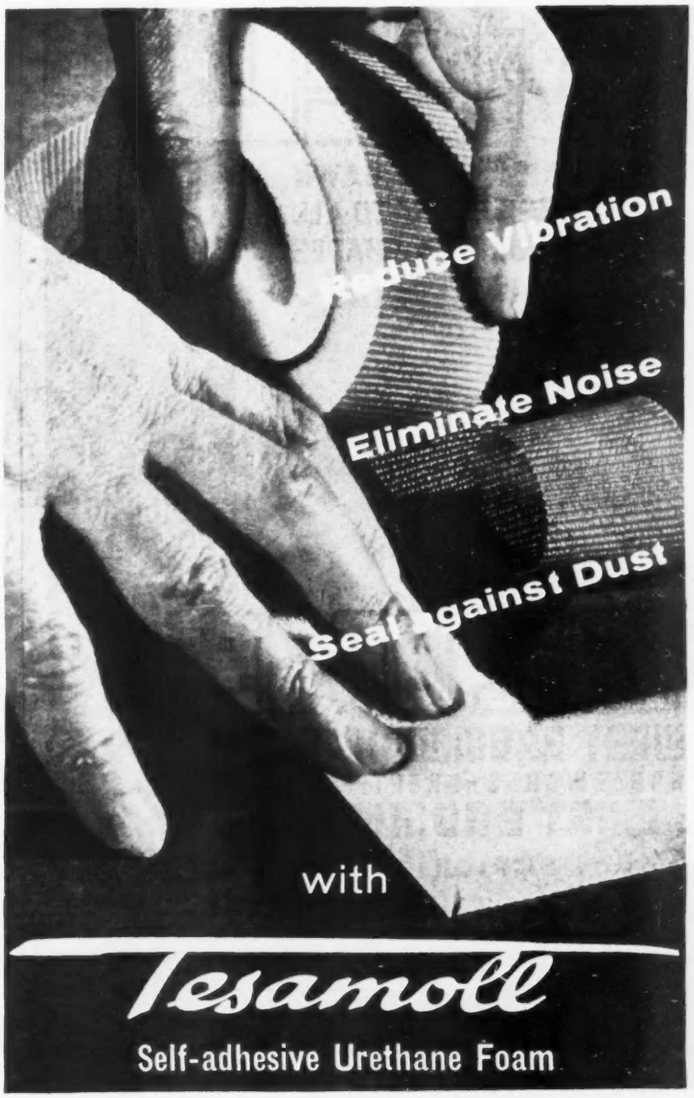

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SAVE TIME Tesamoll has a powerful pressure-sensitive adhesive which adheres firmly and instantly to any dry, clean surface. Self-adhesive Tesamoll saves many man-hours, is clean and quick to use and efficient in operation.

TESAMOLL Can help you too. Tell us your problem, we may well have the answer. Please ask for samples for testing.

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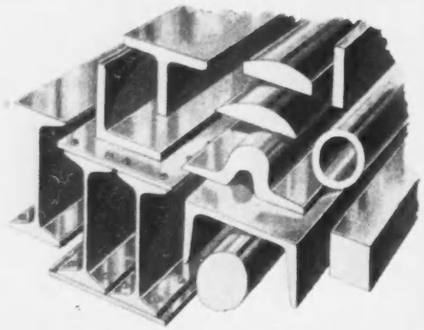

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Saves Chemicals—Loss of Heat, Waste of Water and the Valuable Time of your Chemist in routine testing.

Here is what the Chief Engineer of Alex. Cowan & Sons Ltd., Valleyfield Mills, the well-known paper manufacturers, had to say about the "Crockatt" Densometer. "Heat losses caused by excessive blow-down have been greatly reduced since installing the "Crockatt" Densometer in our Boiler Plant, as due to the effectiveness and efficiency of the instrument and the facility of having a constant indication, we are able to maintain the blow-down rate at a minimum"

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IN CERTAIN CIRCUMSTANCES TRIAL INSTALLATION CAN BE ARRANGED

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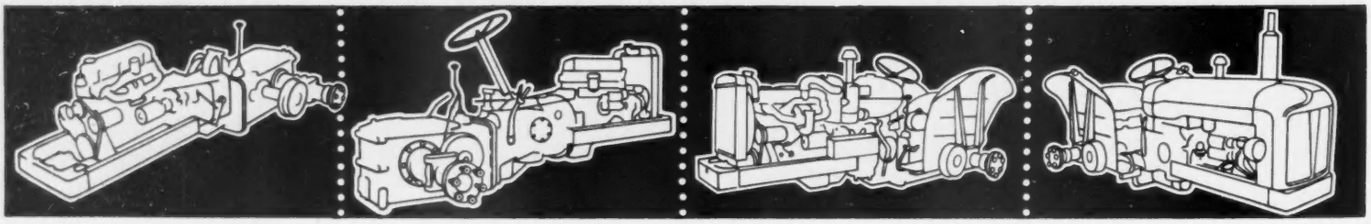

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They look for Fordson Power because it gives equipment the stamp of reliability, ensures high output at low cost, and because it has the backing of the Ford world-wide service and spares organisation. There are Fordson Industrial Units in the 30-40 and 40-50 b.h.p. classes, in more than 100 different assemblies. Fit Fordson and you get all the benefits of quality mass-production from Ford's famous Dagenham factory, the biggest producer of mobile power units. Fit Fordson, the unit tailor-made to your requirements. Send for detailed specifications today.

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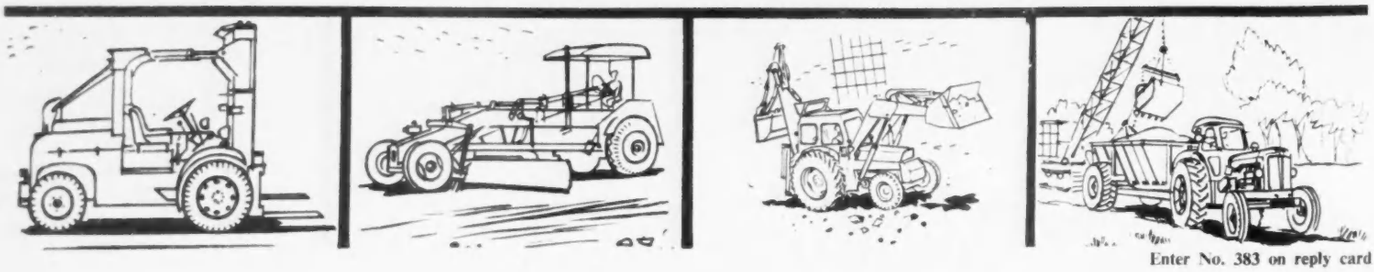

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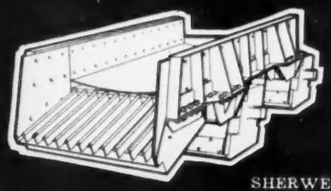
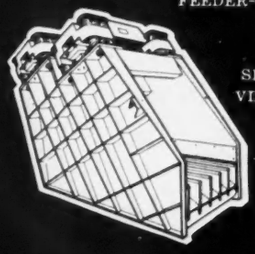
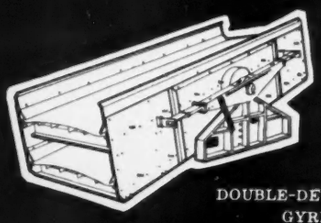
if the problem is screening, profit by our experience



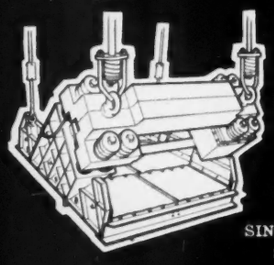
SHERWEN VIBRATING FEEDER-GRIZZLY



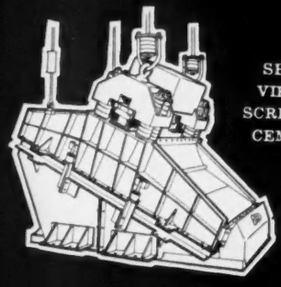
SHERWEN VIBRATING GRIZZLY



DOUBLE-DECK GYREX FEEDER



SINGLE-DECK SHERWEN SCREEN



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G.E.C. mineral dressing plant

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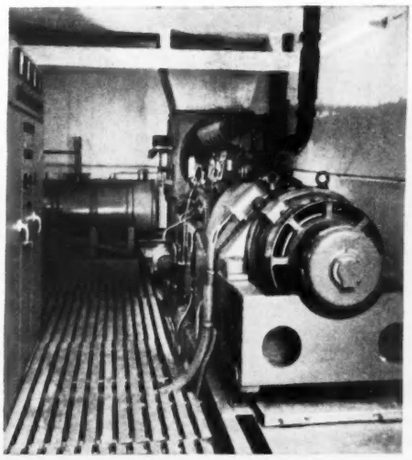
There are three good reasons for this: Firstly, the Mercedes-Benz engine programme comprises 24 types, with horsepowers ranging from 17 to 3000 b. h. p., so that it meets every power requirement occurring in practice.

Secondly: Mercedes-Benz diesels — water-cooled four stroke designs with precombustion chamber, of vertical or horizontal in-line types or of V arrangement, supercharged or unsupercharged — are as powerful, dependable and durable as all Mercedes-Benz products.

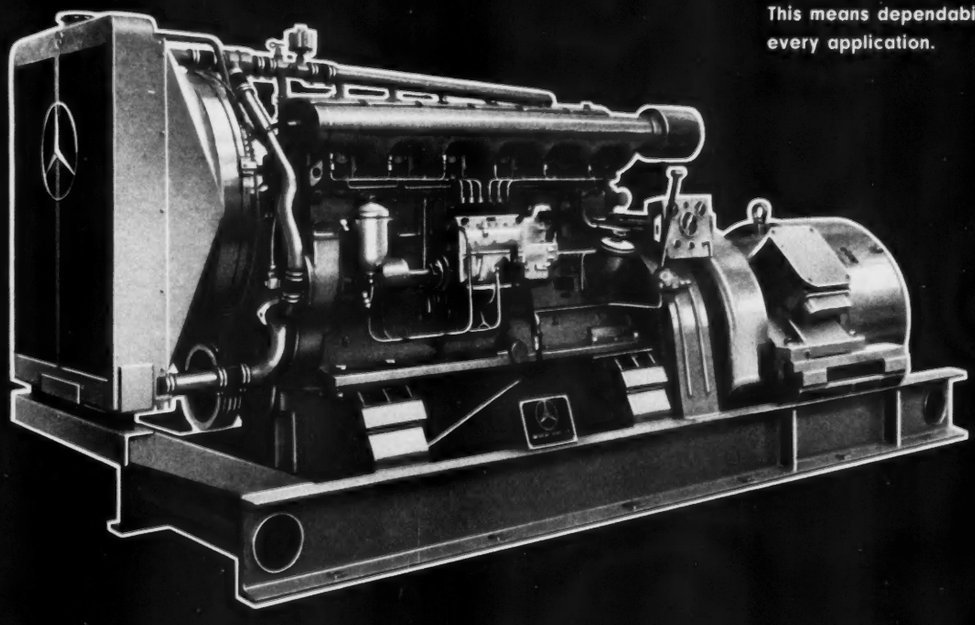
And thirdly: At hundreds of service stations scattered all over the world there are skilled mechanics to keep every Mercedes-Benz diesel operating at top performance.

Mercedes-Benz diesels therefore offer all the properties required for economical and reliable operation.



Quality is dependable

Mercedes-Benz diesel engines have many good qualities: They supply a maximum of power for a minimum of fuel; their simple, rugged design makes for easy maintenance, and they will retain their high performance over a long period of years. But their most important advantage is their outstanding quality: This means dependability for every application.



974 MA1

MERCEDES-BENZ DIESEL

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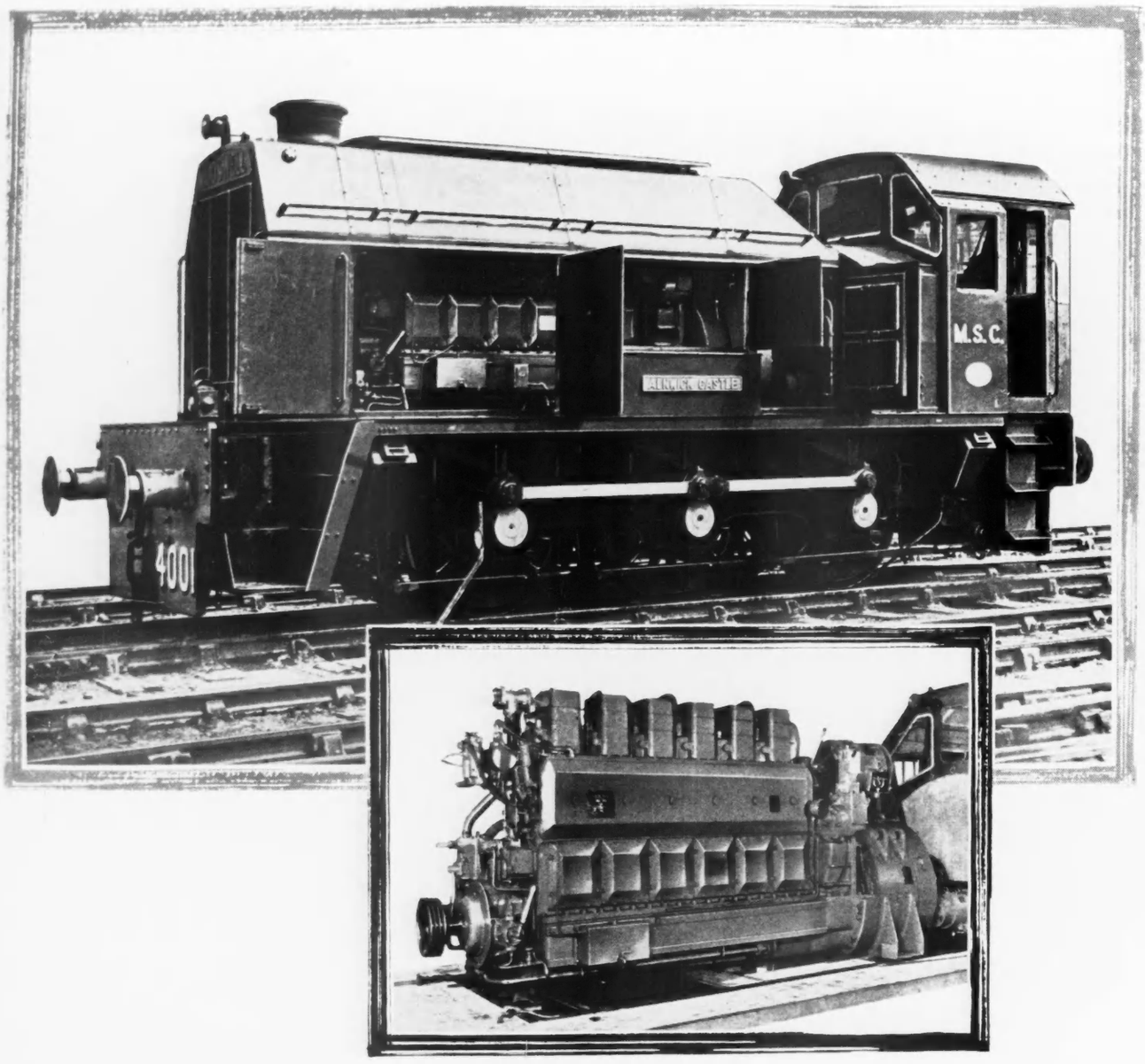

Manchester Ship Canal Company's first diesel locomotive powered by NATIONAL

The " Alnwick Castle," a Hudswell Clarke 50 ton 0-6-0 diesel electric locomotive, is powered by a 400 b.h.p. normally aspirated six cylinder National diesel engine, fitted with a Brush flange mounted alternator and resiliently mounted on three point suspension.

Ask for further details on National rail traction diesels ranging from 80 to 864 b.h.p.

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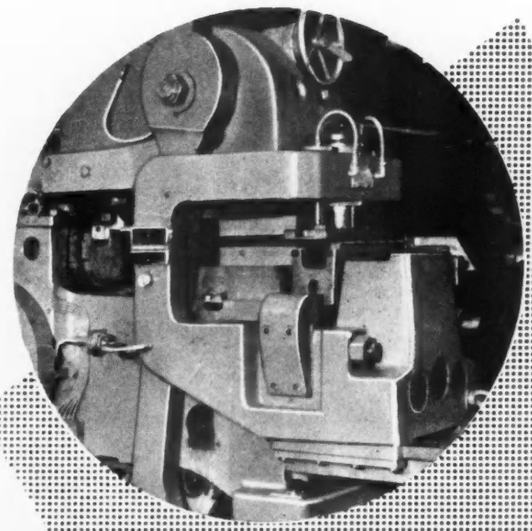

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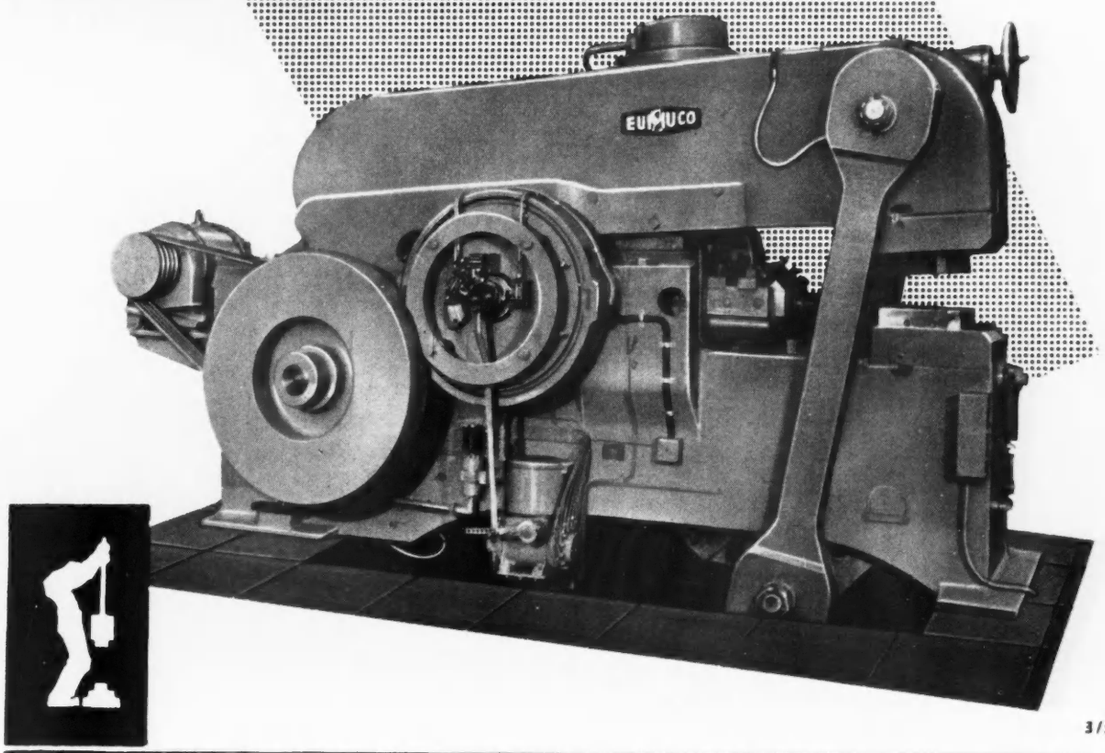

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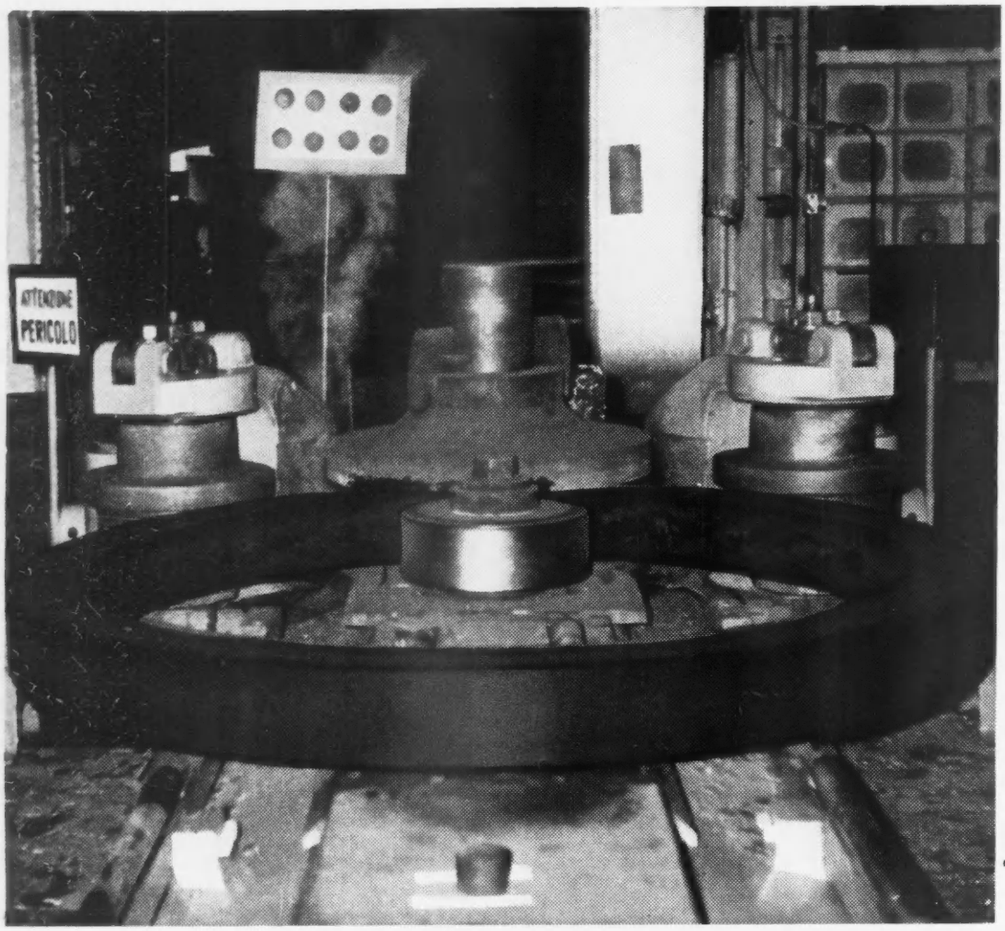

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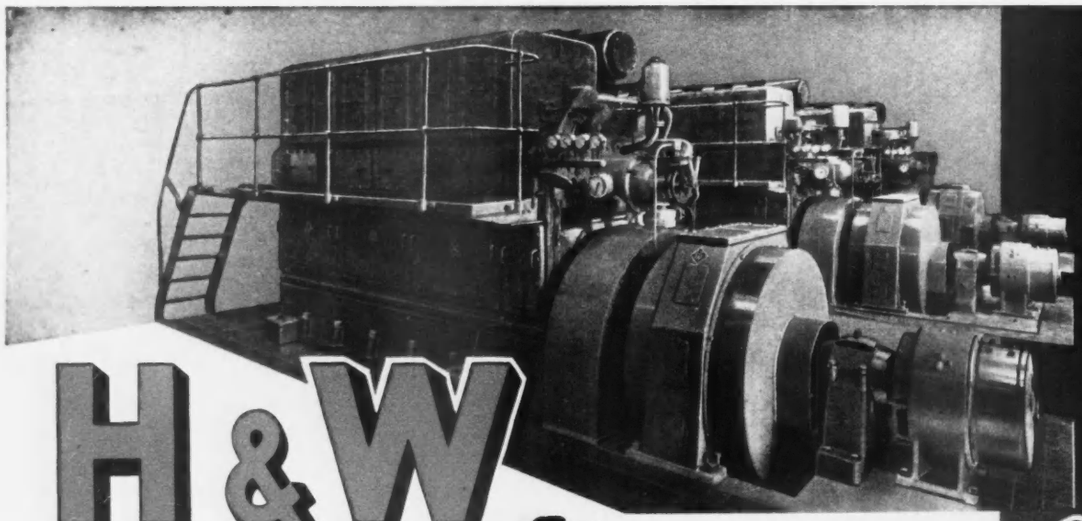

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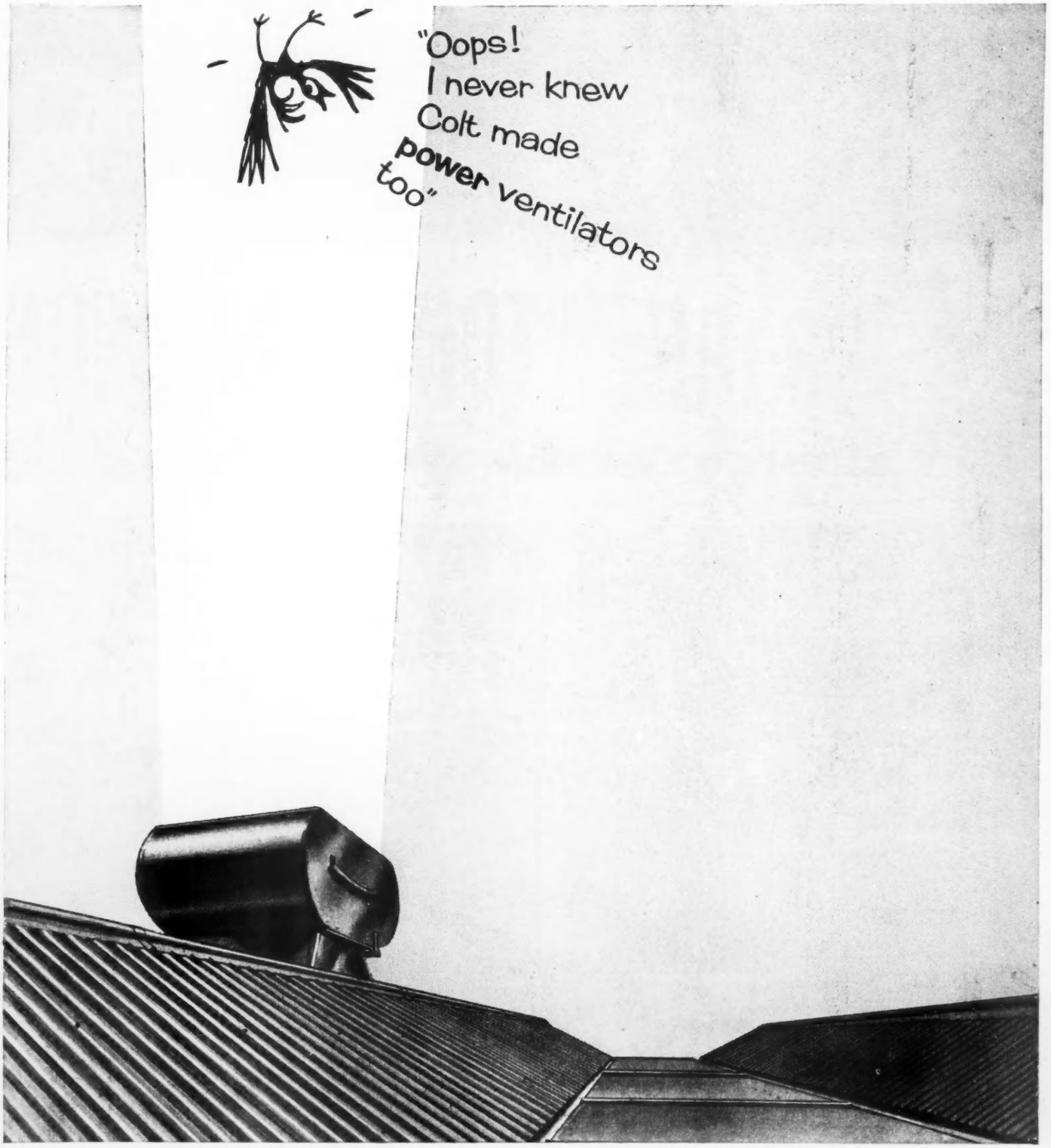

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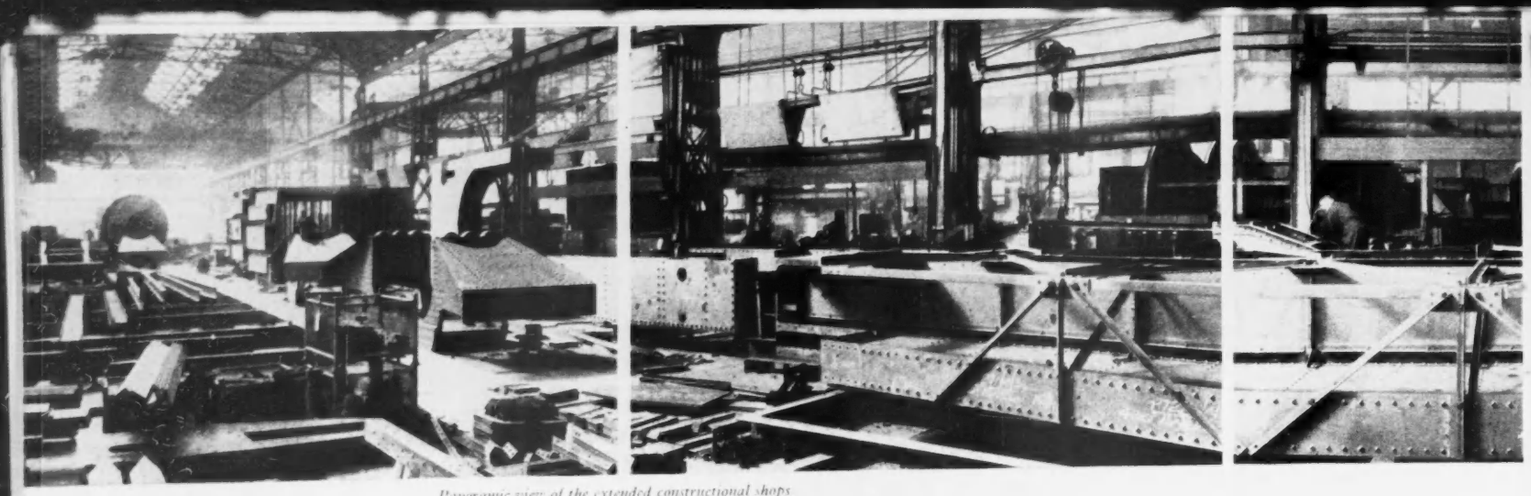
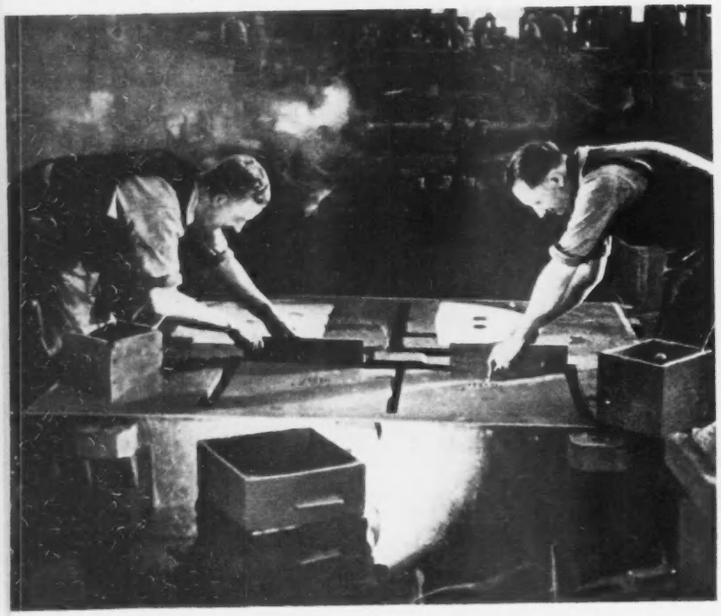


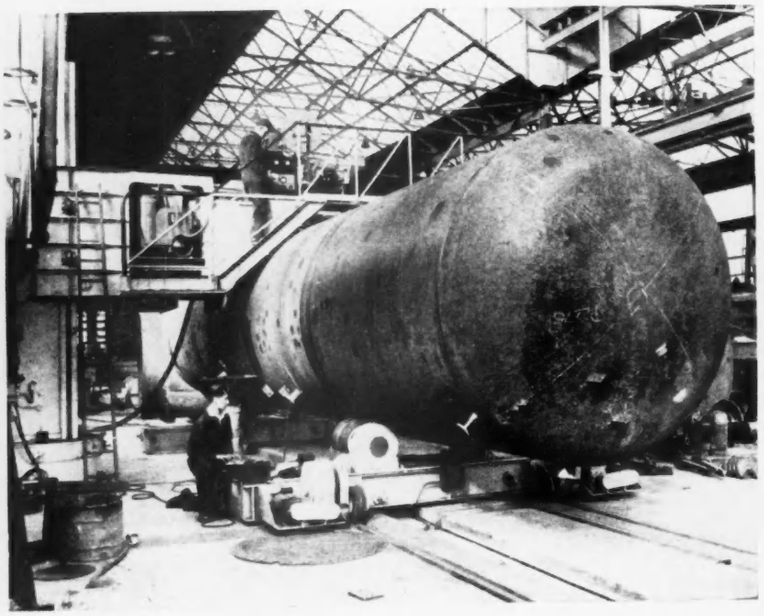
Panoramic view of the extended constructional shops

NEWTON CHAMBERS

New production facilities



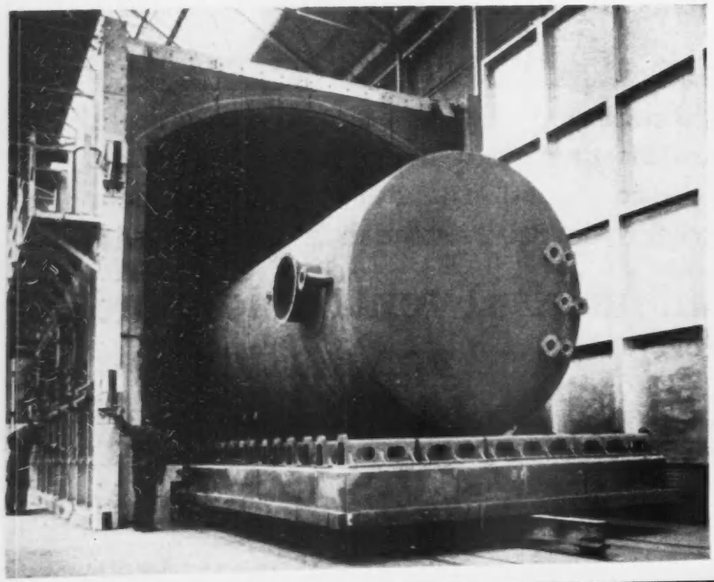
Preparing to cast in Meehanite metal in the foundries.

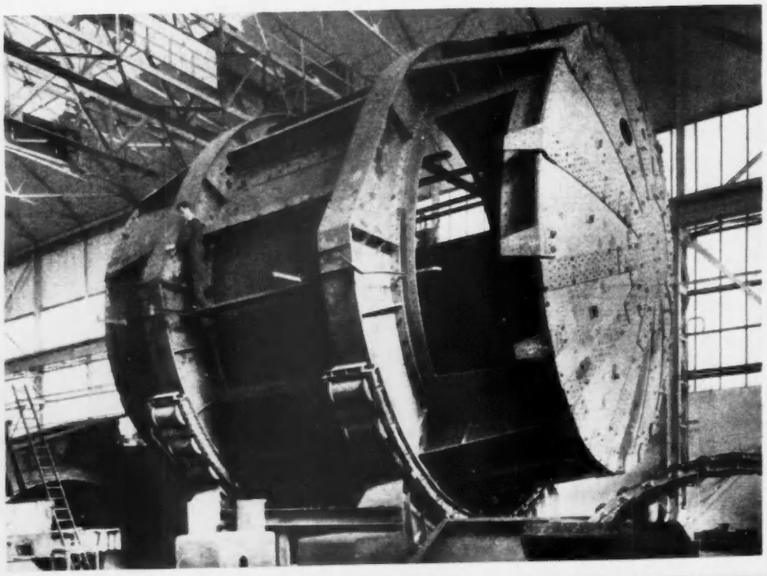


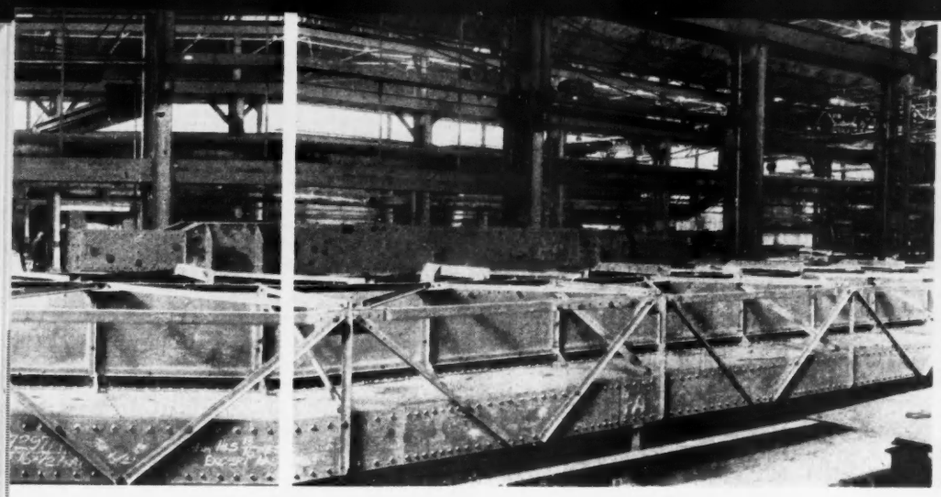
Automatic welding of a large pressure vessel.

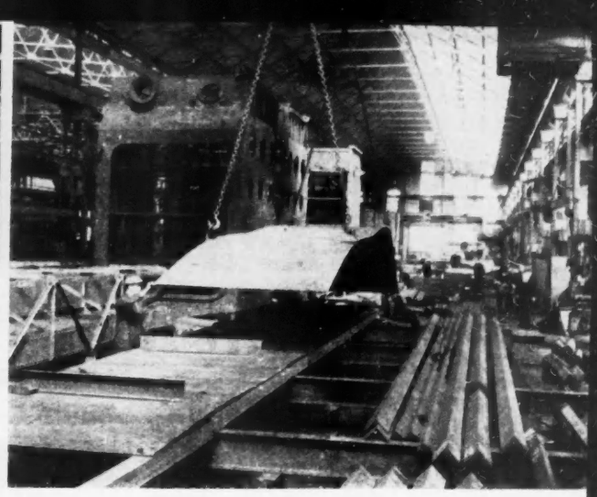
The large new stress relieving furnace in use.

Hot metal mixer of 800-tons capacity under assembly.









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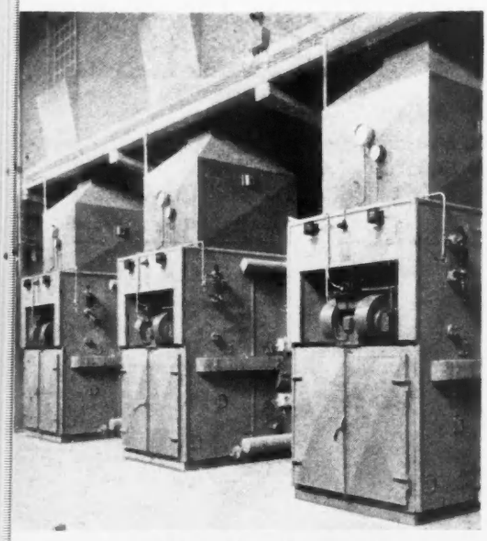

A Redfyre "Emma" Boiler installation.

MODERN FOUNDRY TECHNIQUES, including iron castings of all types and sizes in Meehanite metal.

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AUTOMATIC WELDING, x-ray examination and stress relieving.

NEW HEAT EXCHANGE DEVELOPMENTS, including the INKA Preheater, Struthers Wells direct-fired Heaters and indirect heating systems.

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Newton Chambers

ENGINEERING DIVISION

NEWTON CHAMBERS AND COMPANY LIMITED
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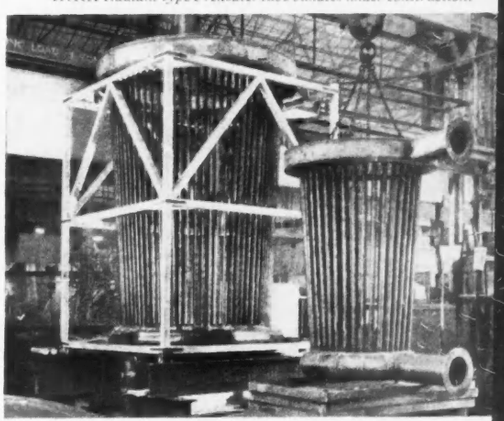
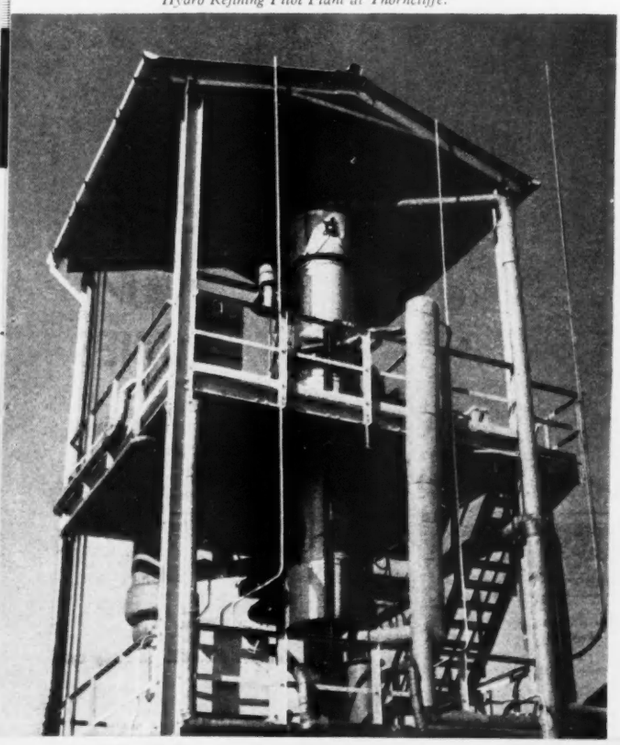
INKA Radiant type Preheater tube bundles under construction.

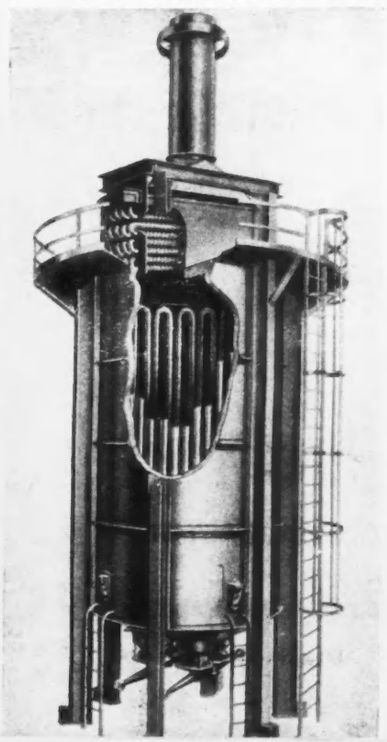


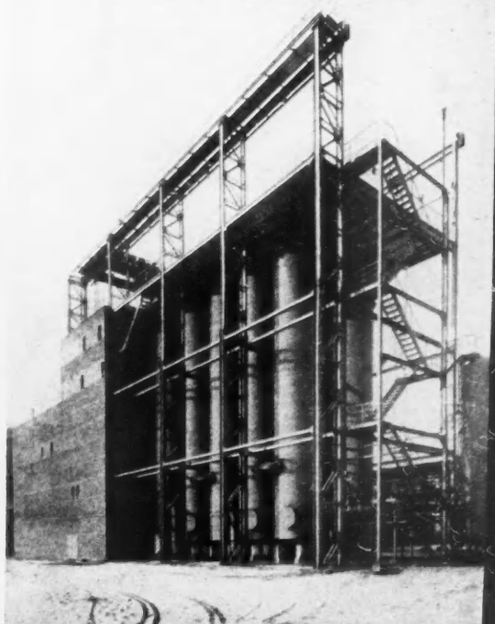
A typical Newton Chambers Bischoff high pressure purification plant.

Hydro Refining Pilot Plant at Thorncliffe.



Struthers Wells direct-fired heaters.





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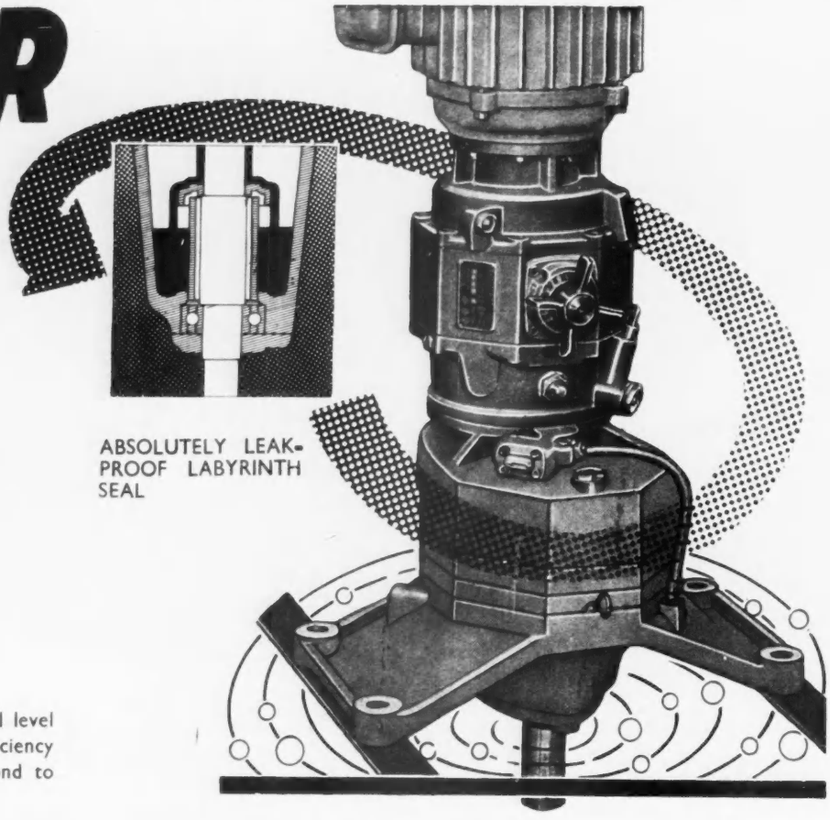

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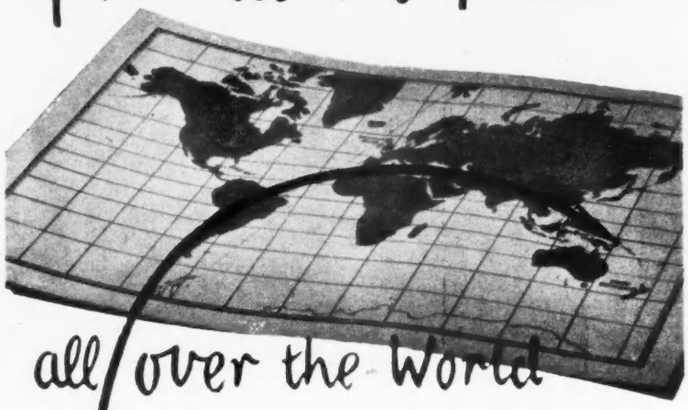
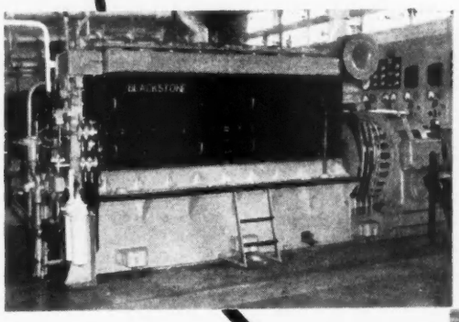
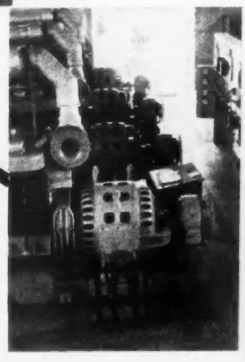


all over the World



IN RABAUL,

New Britain, electricity is supplied by four 320 kW alternators, each powered by a Lister Blackstone EVS8 480 h.p. diesel engine.



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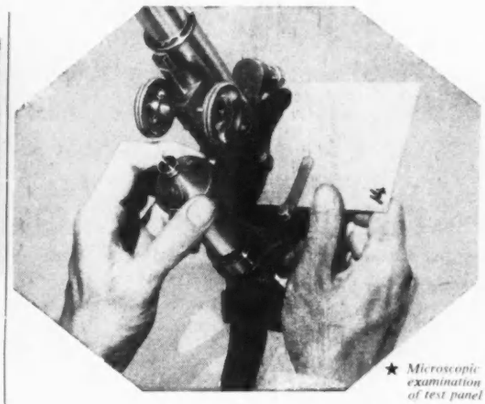

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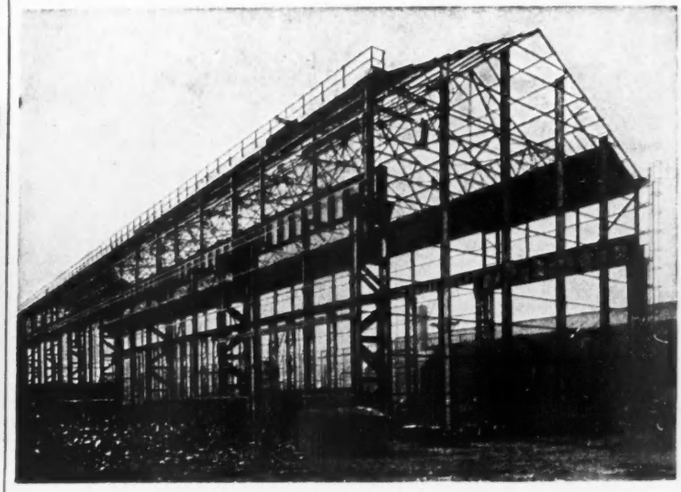

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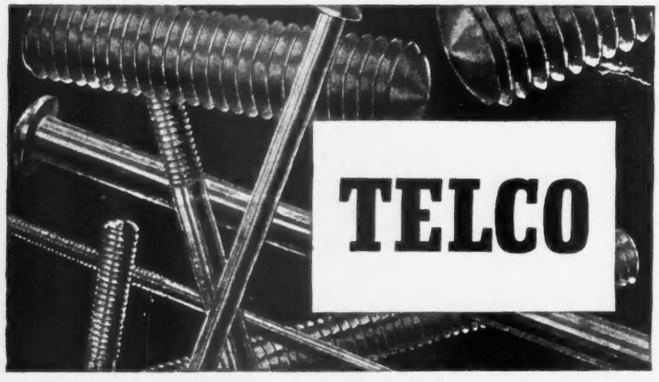

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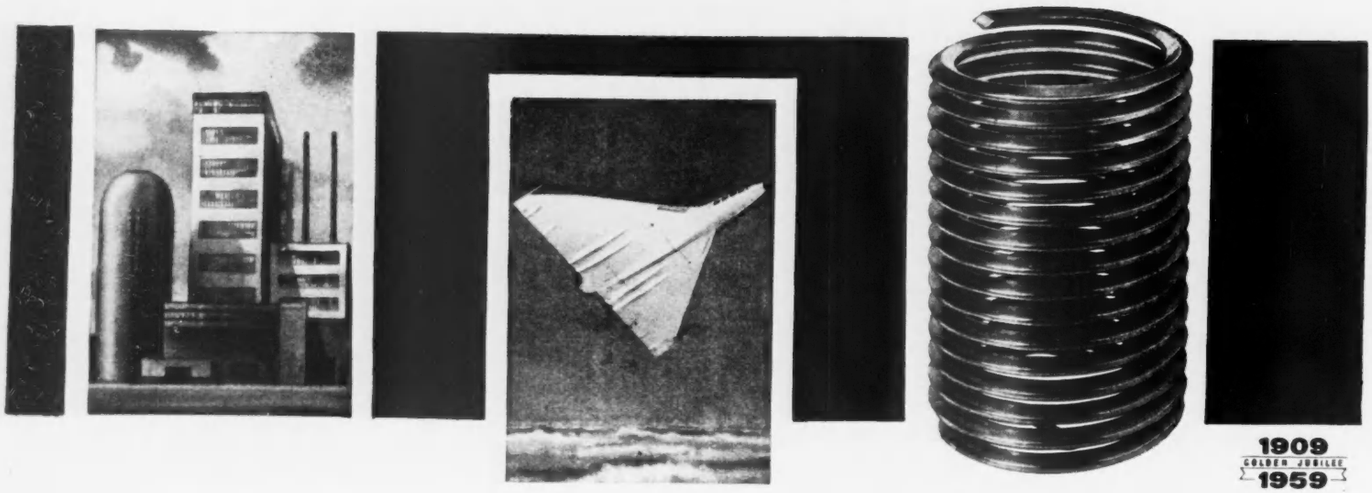

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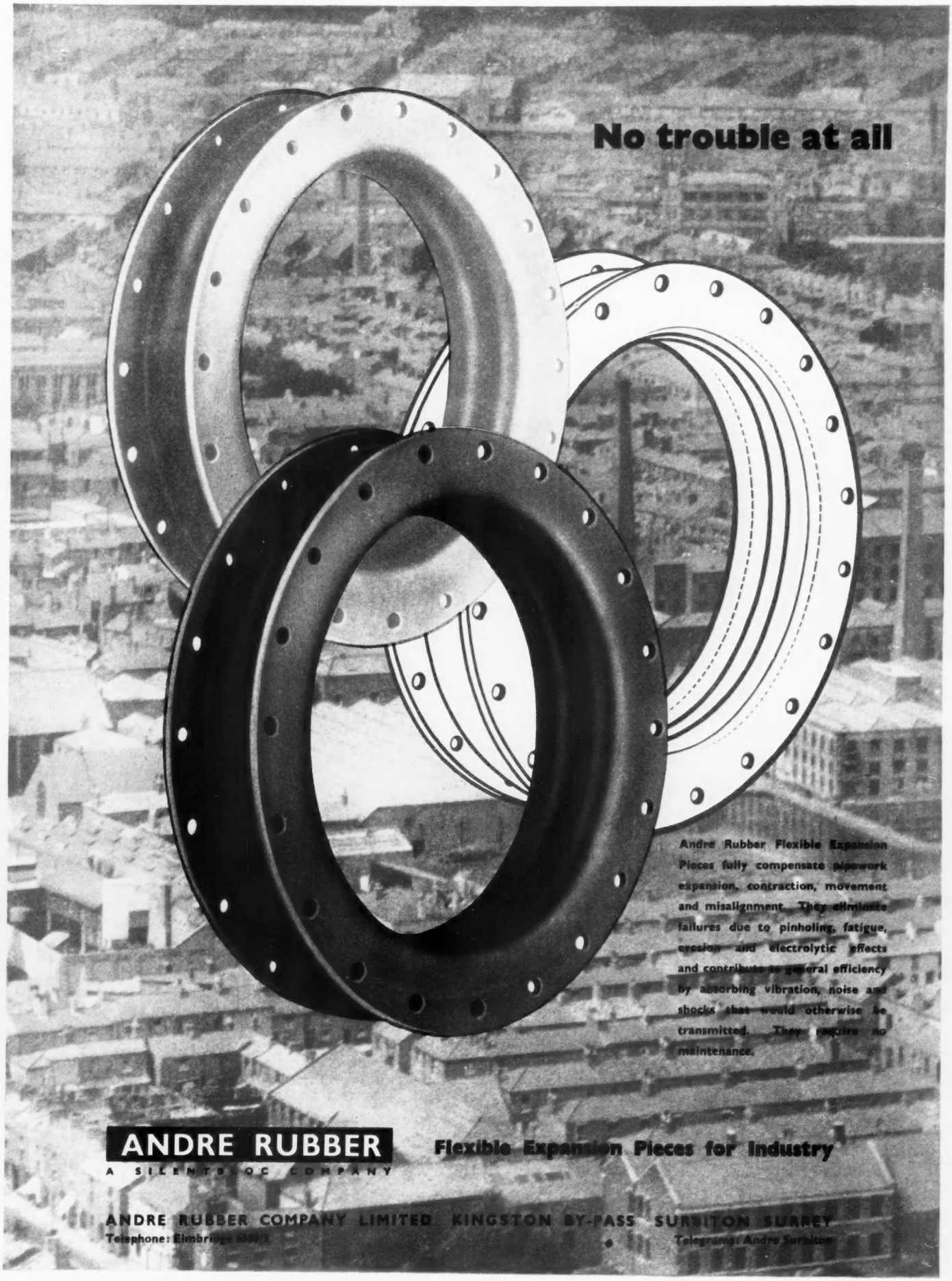
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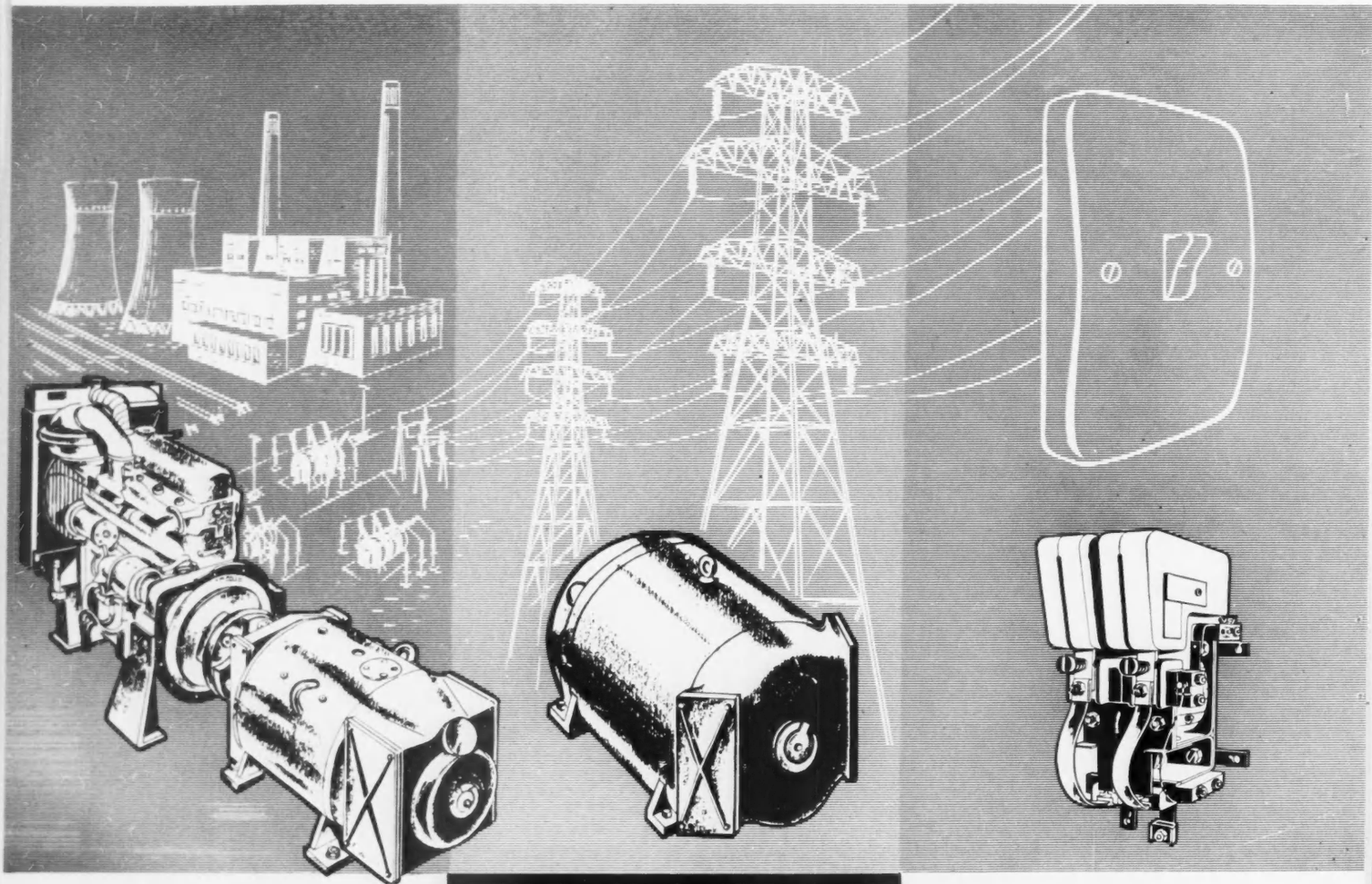

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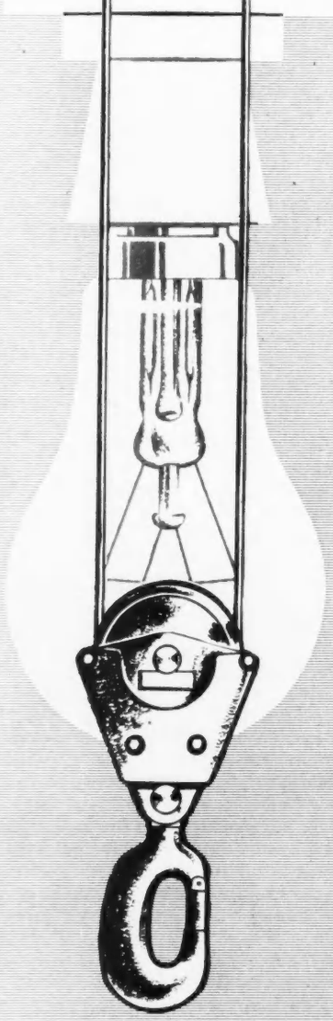

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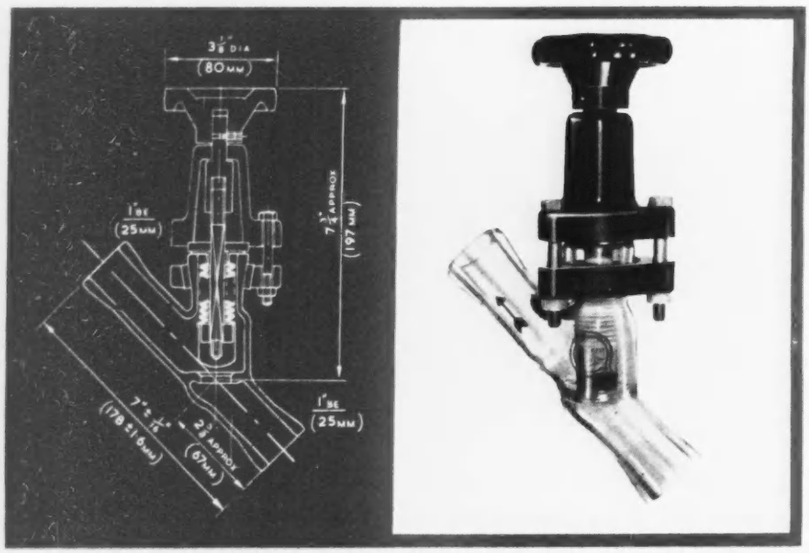

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Cost less to run

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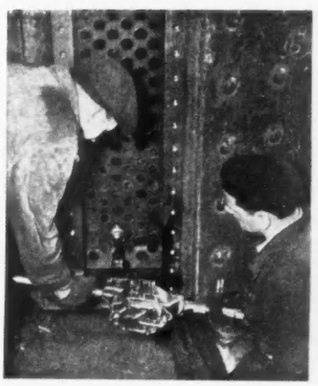

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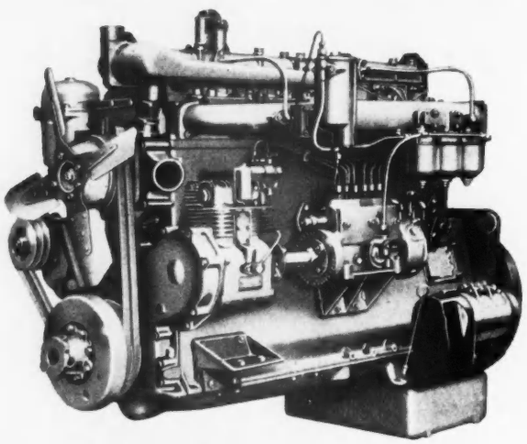

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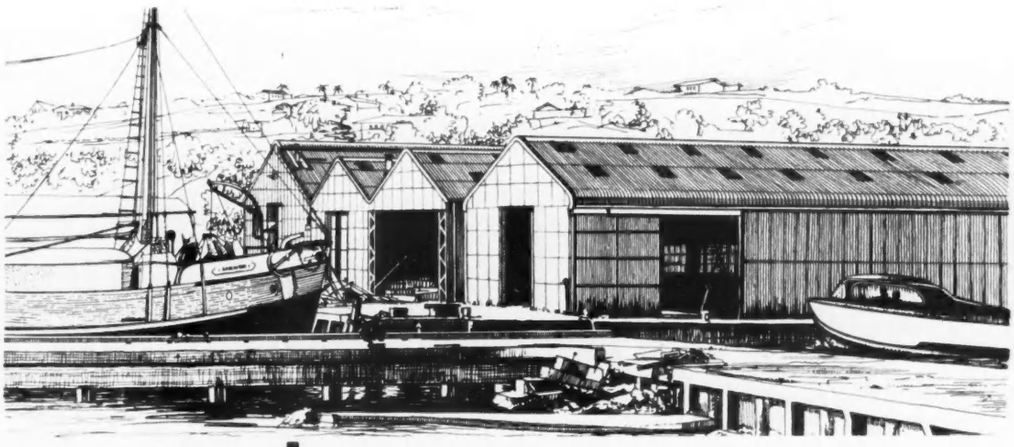

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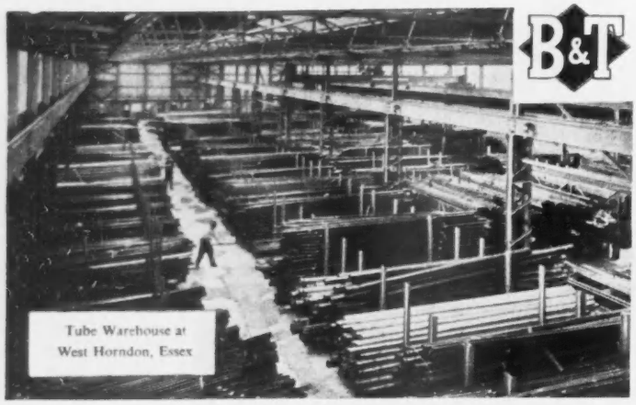

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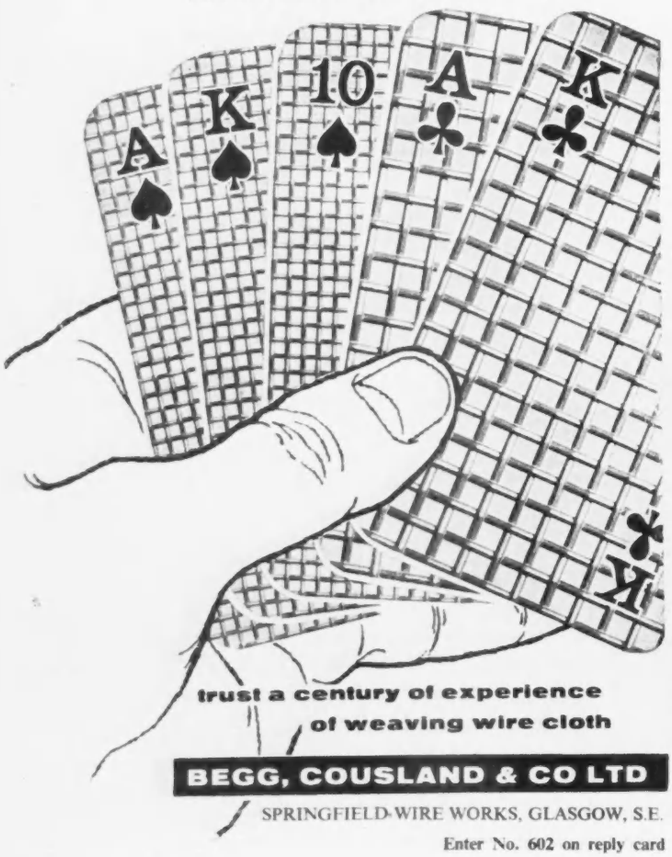

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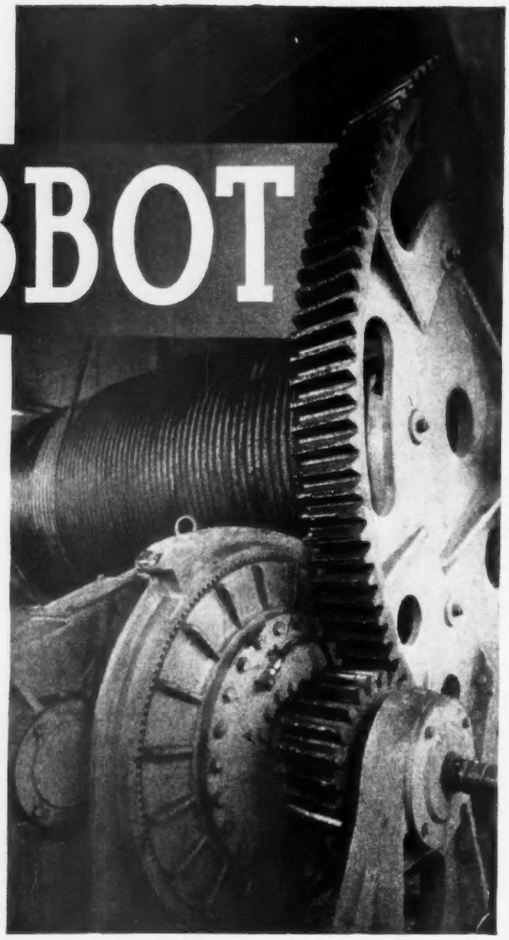

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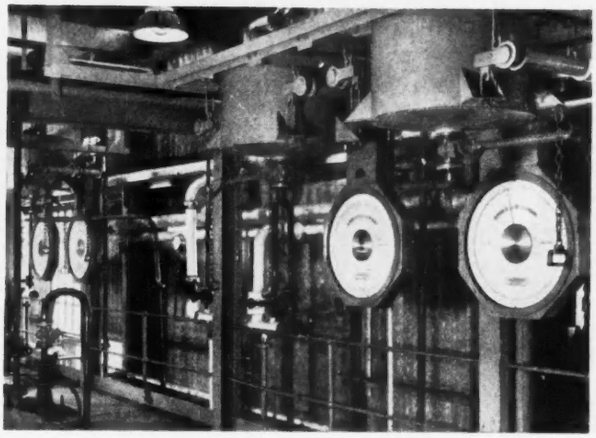

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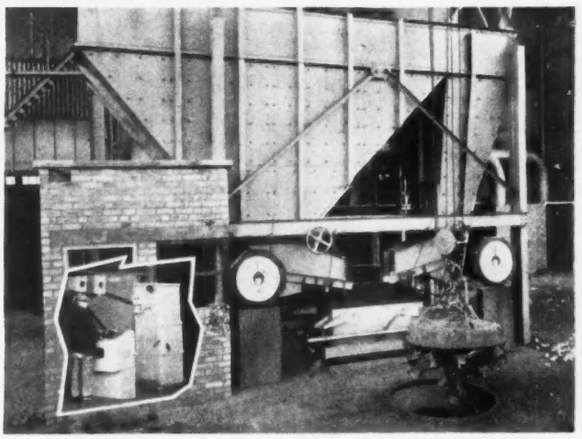

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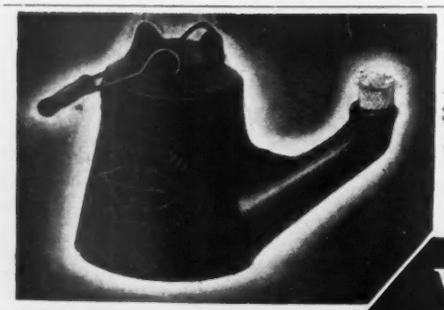

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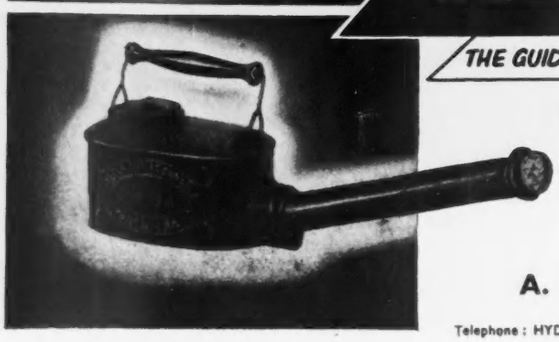

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Also makers of Wells Waste Oil Filters, Oil Storage Cabinets, Barrel Pours, Lathe Drip Cans, Portable Industrial Oil Heaters, Lime Spraying Machines and Spray Guns.

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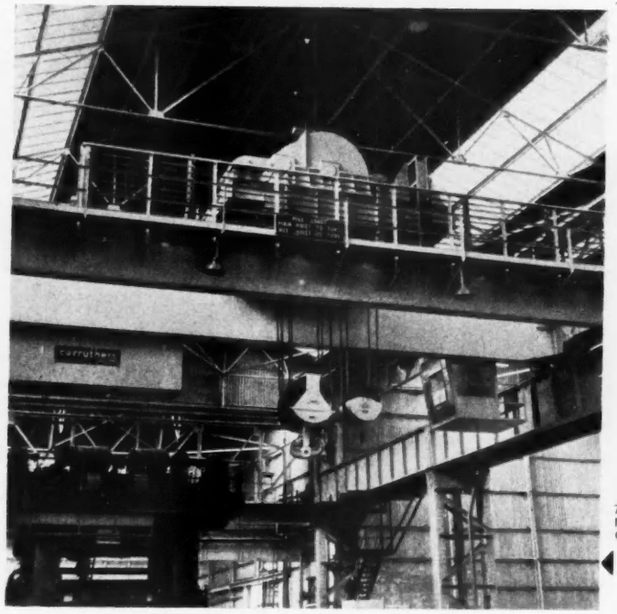

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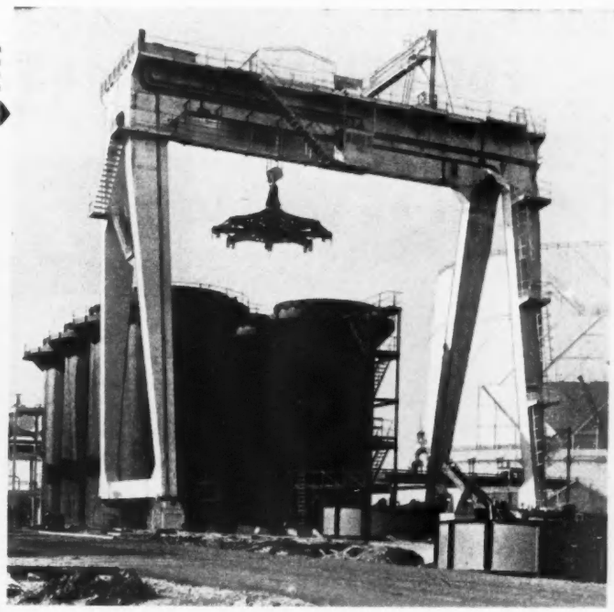

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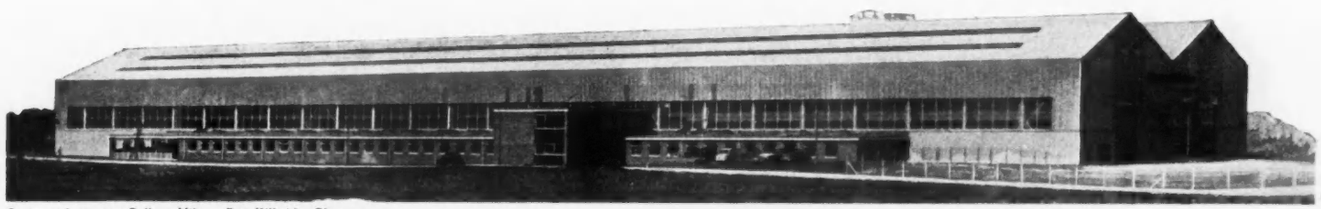

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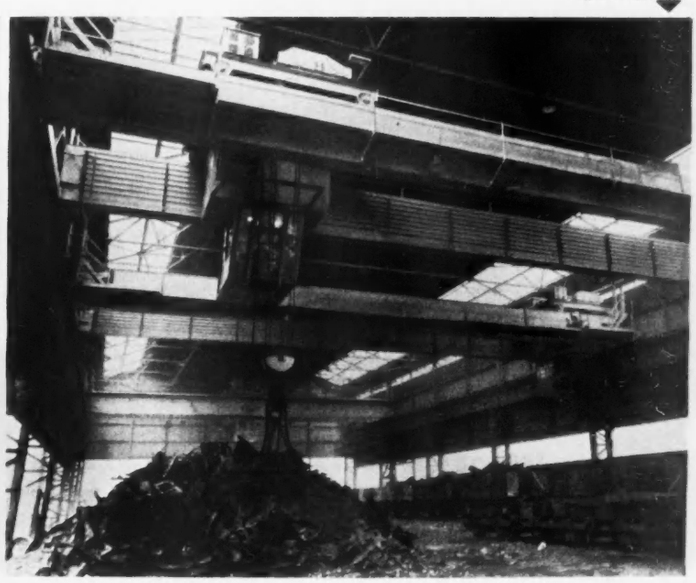

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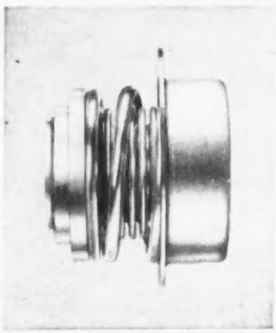

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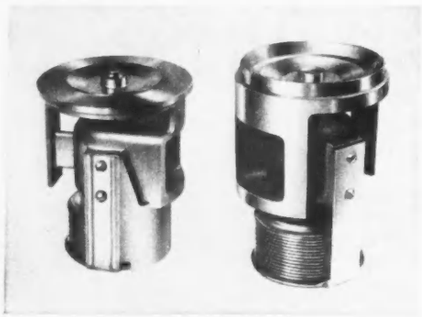

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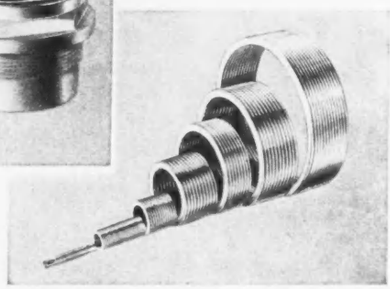

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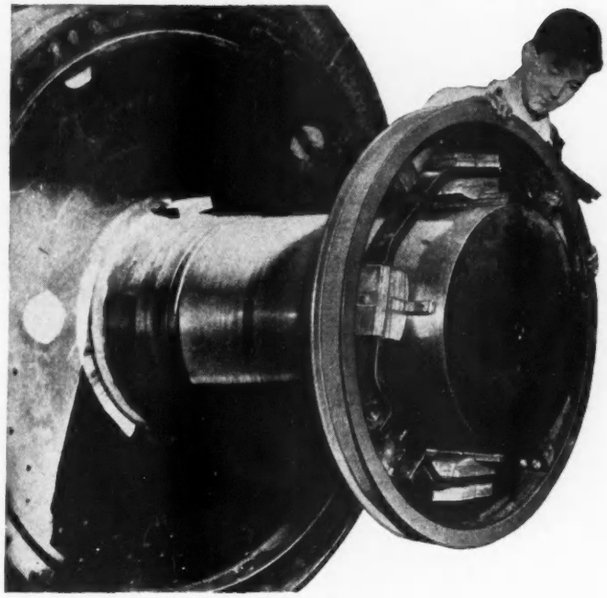

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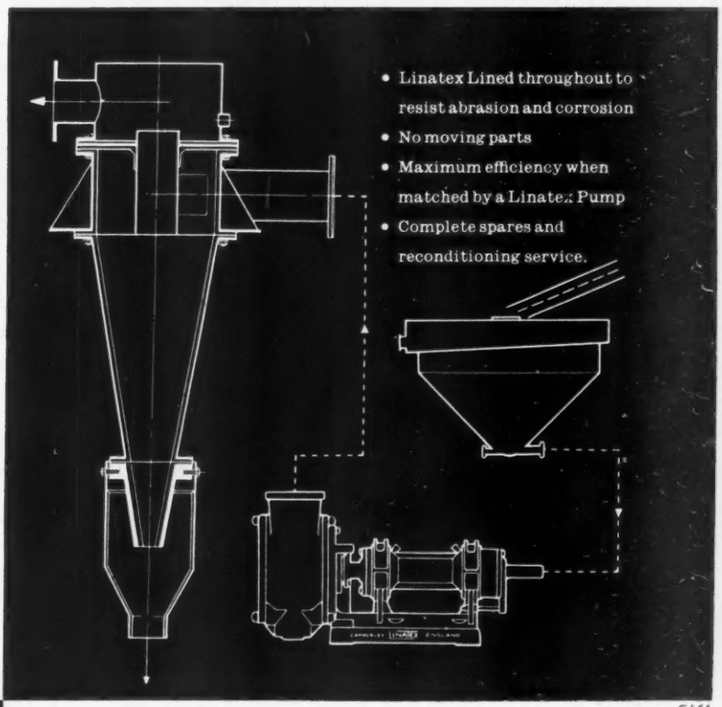
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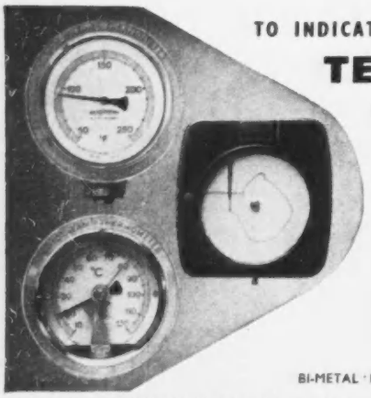

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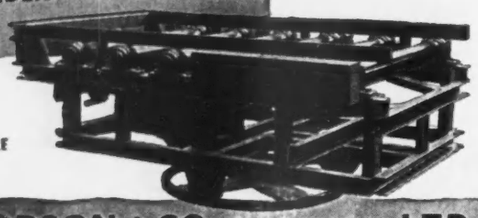

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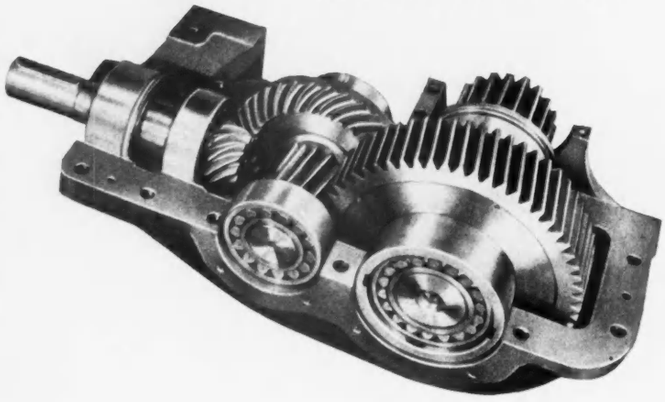

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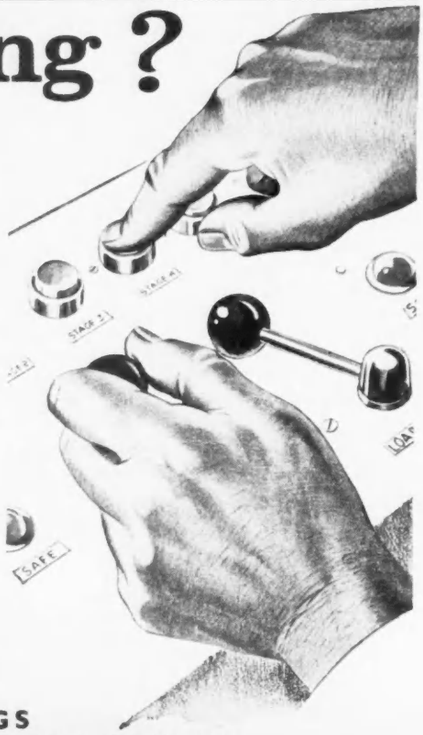

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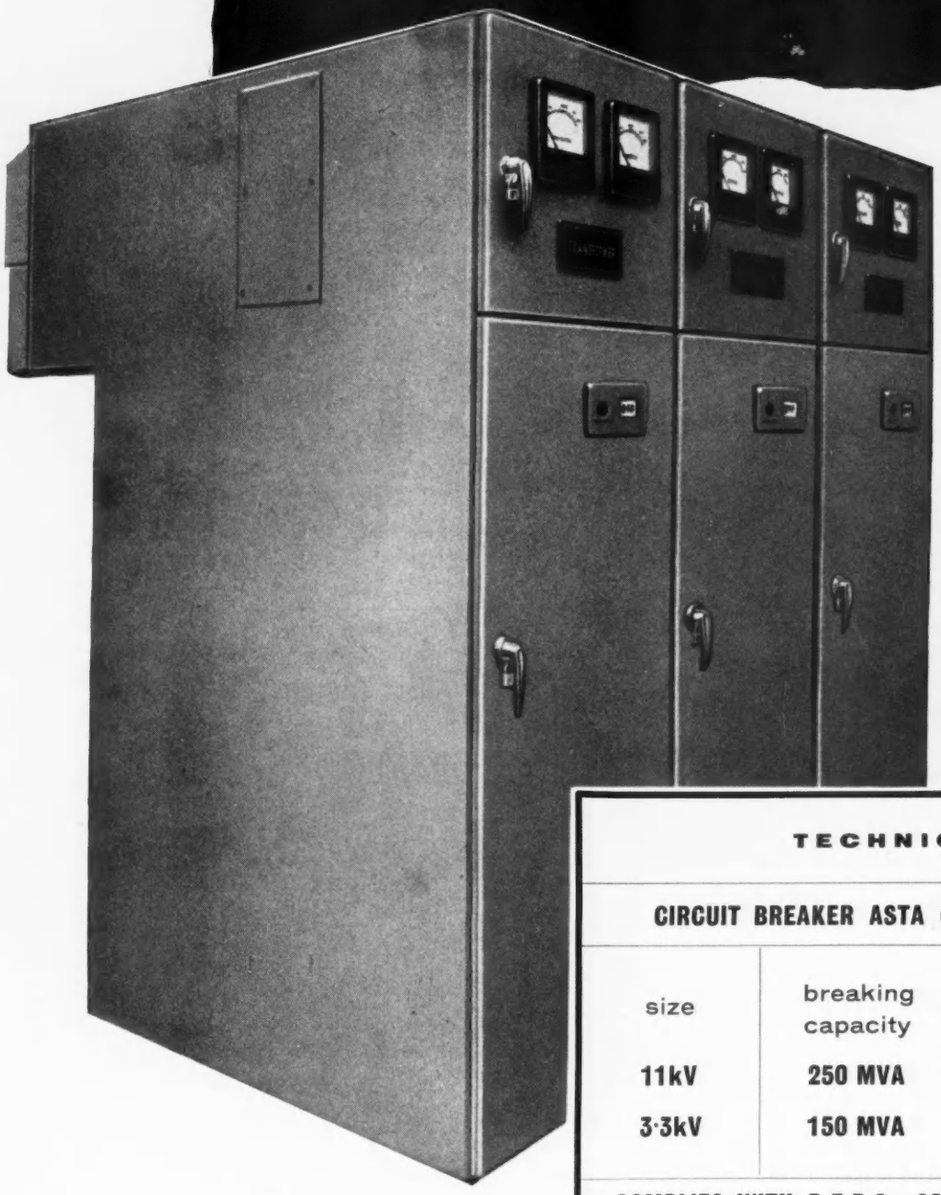

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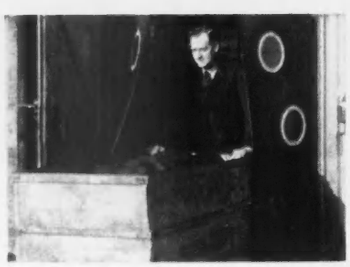

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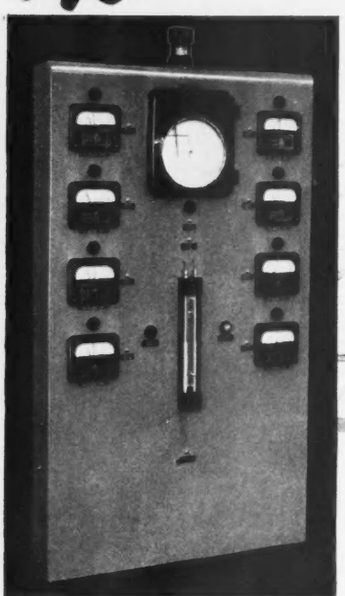

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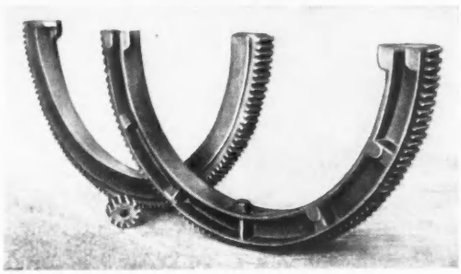

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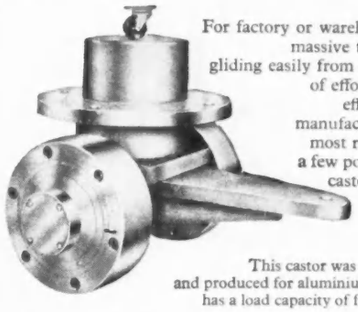

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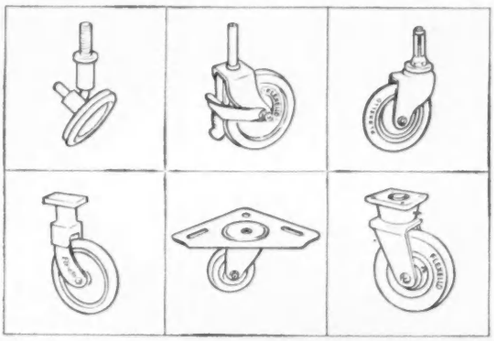

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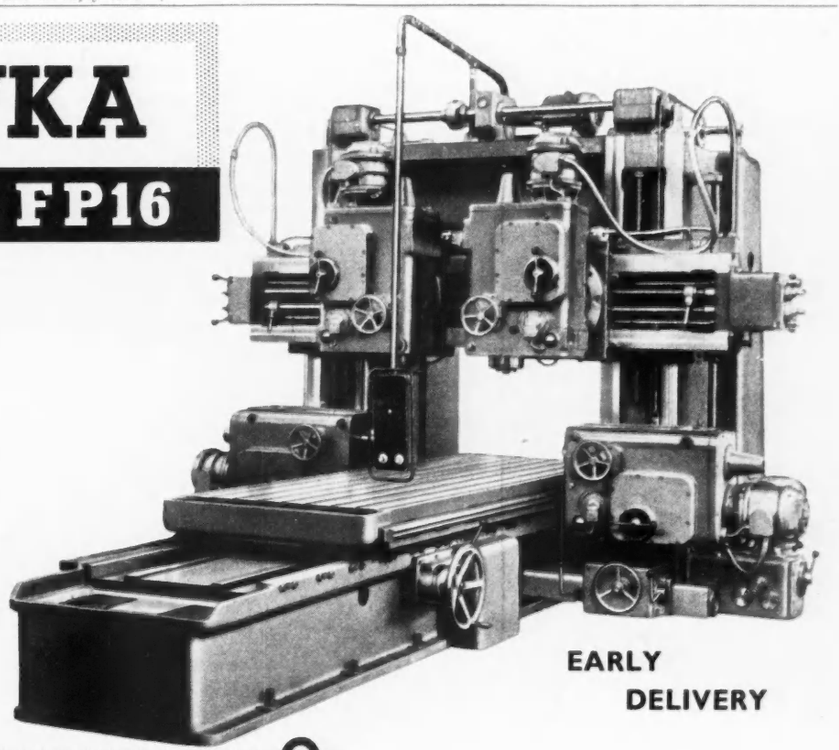

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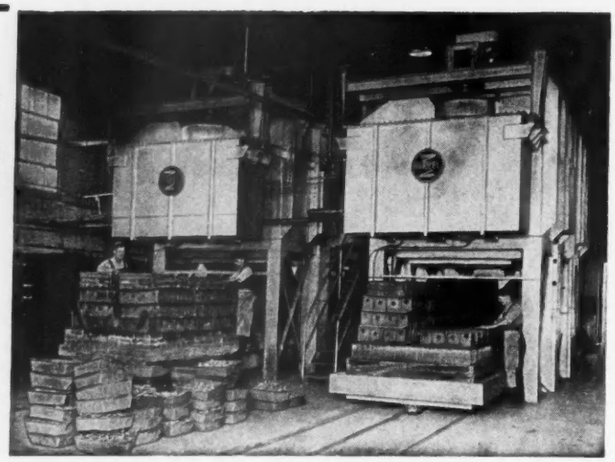

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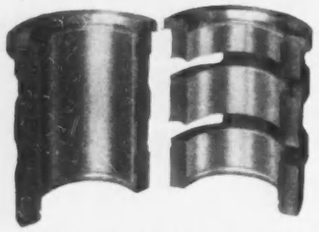

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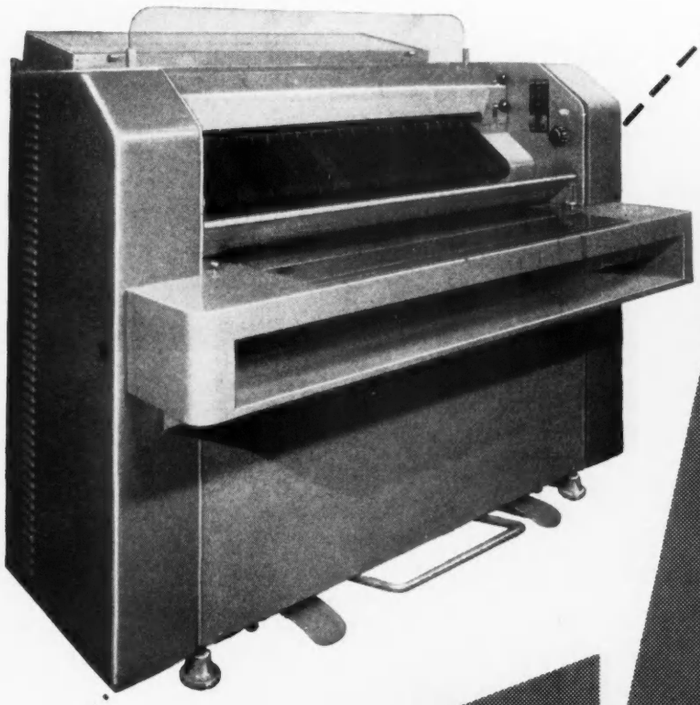

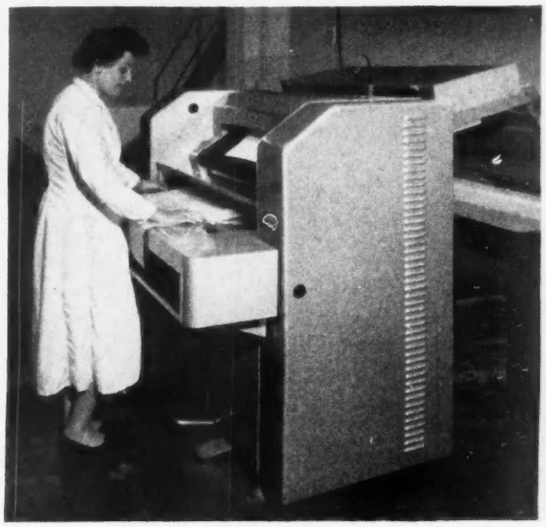

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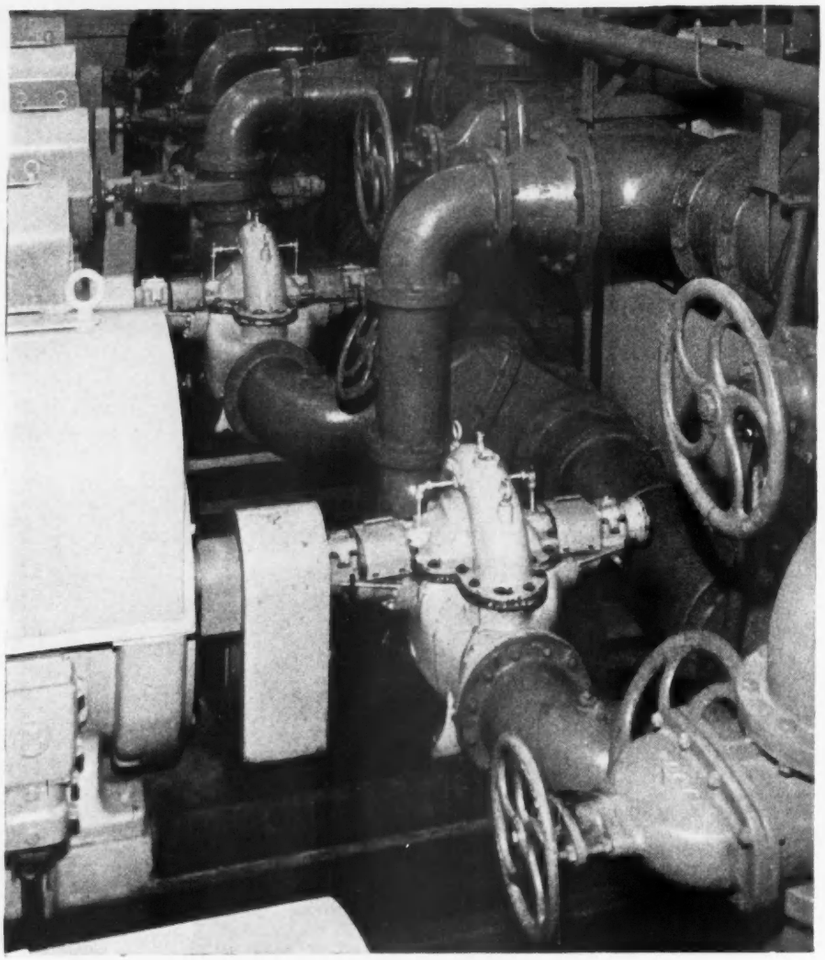

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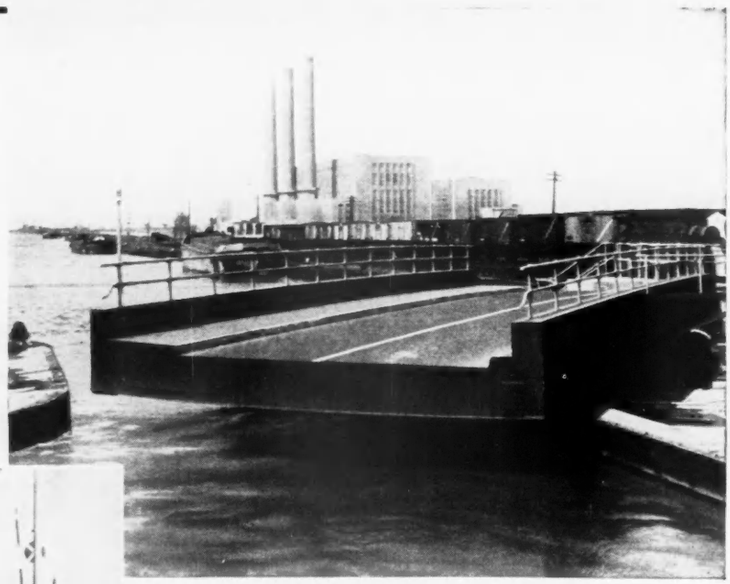

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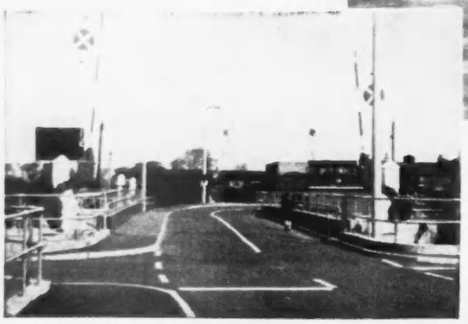

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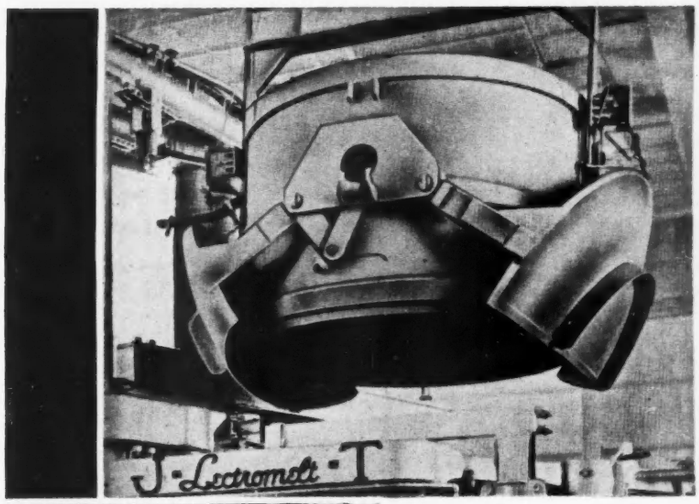
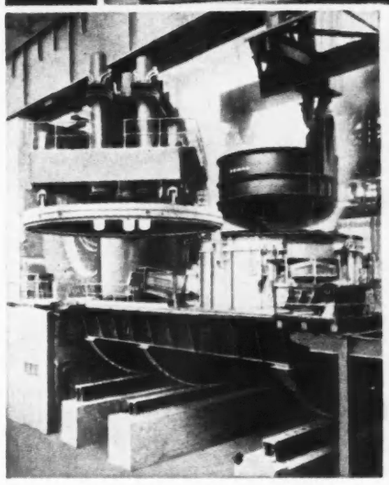


Size "J.T." 18 ft. diameter LECTRO-MELT furnace being quickly charged by a clam shell type charging bucket.



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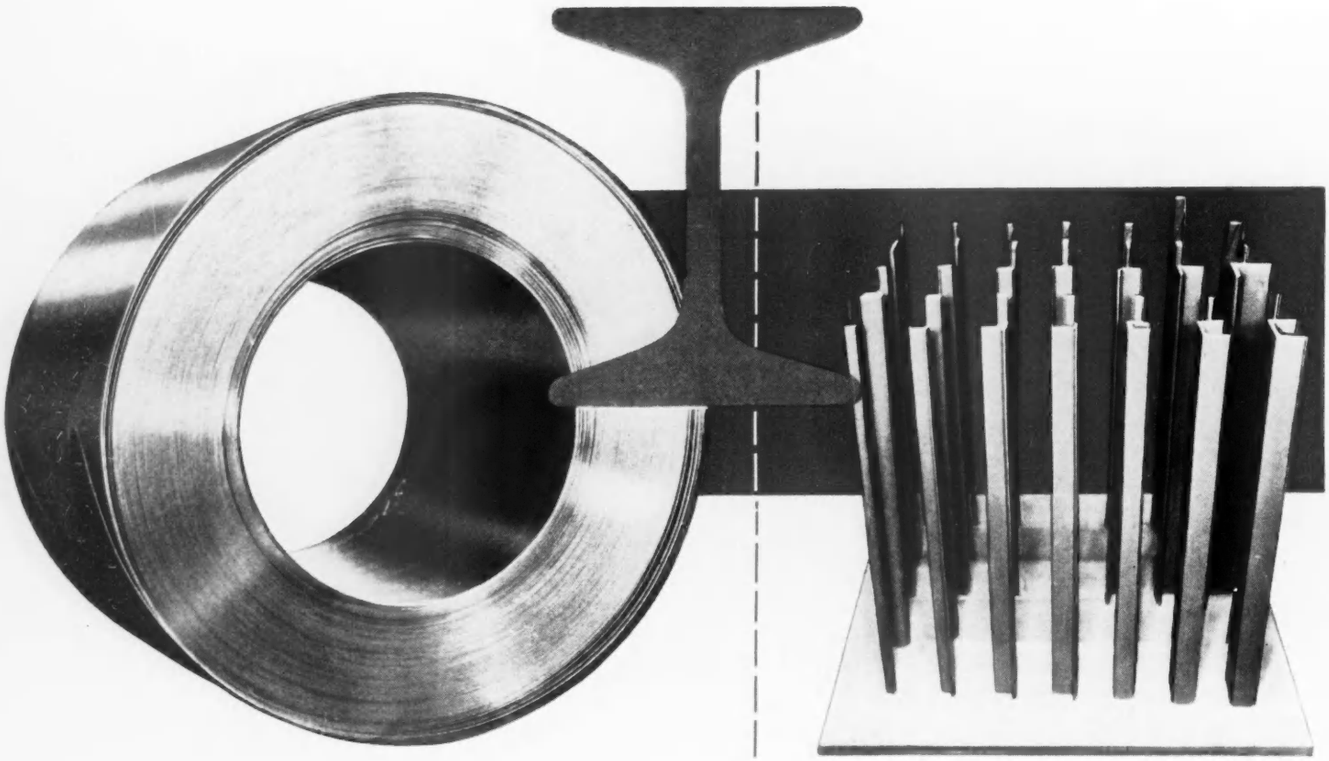

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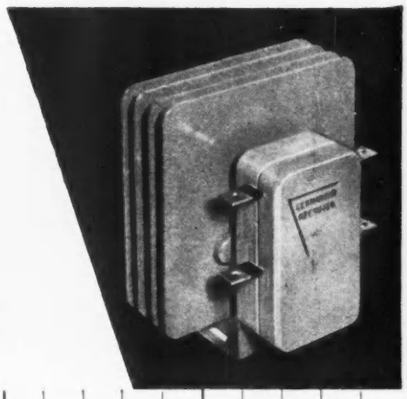

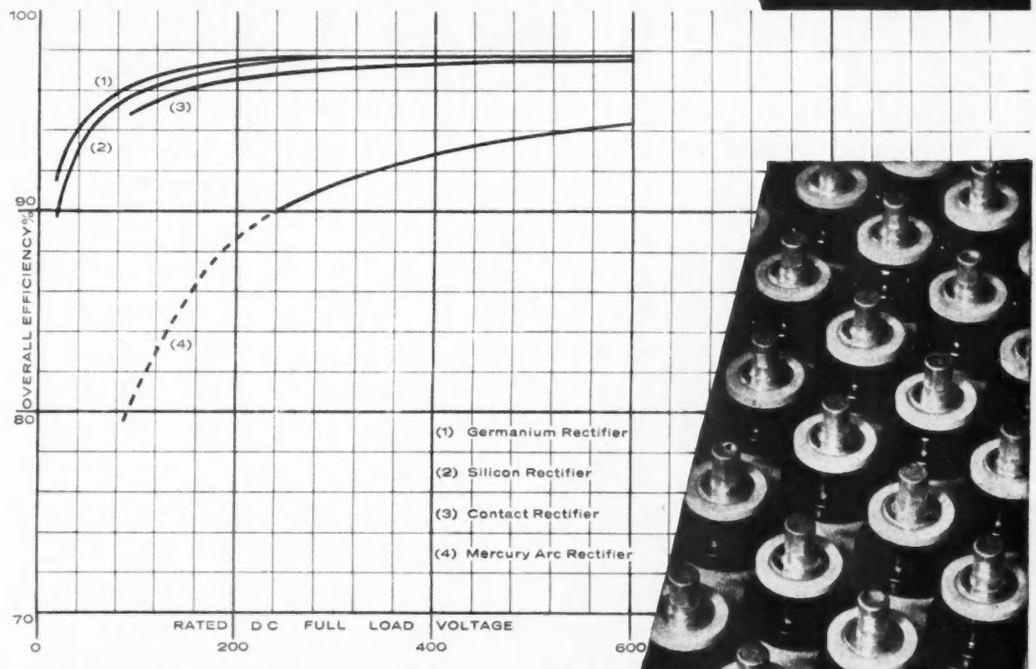

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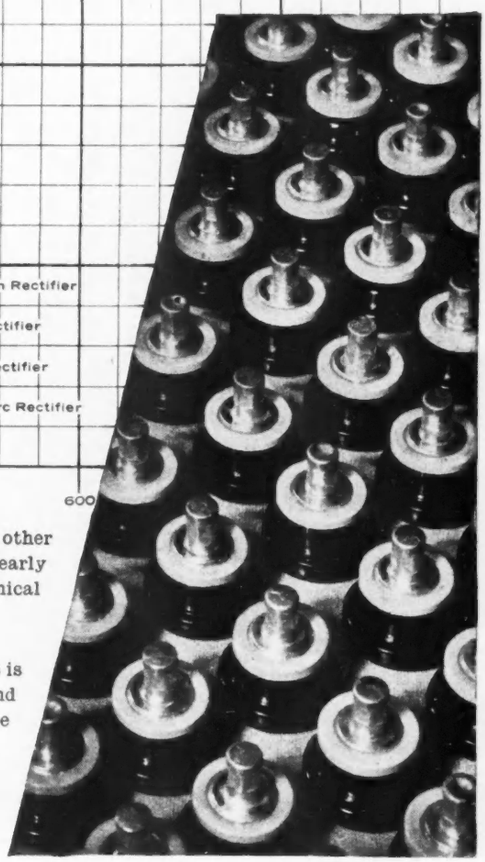

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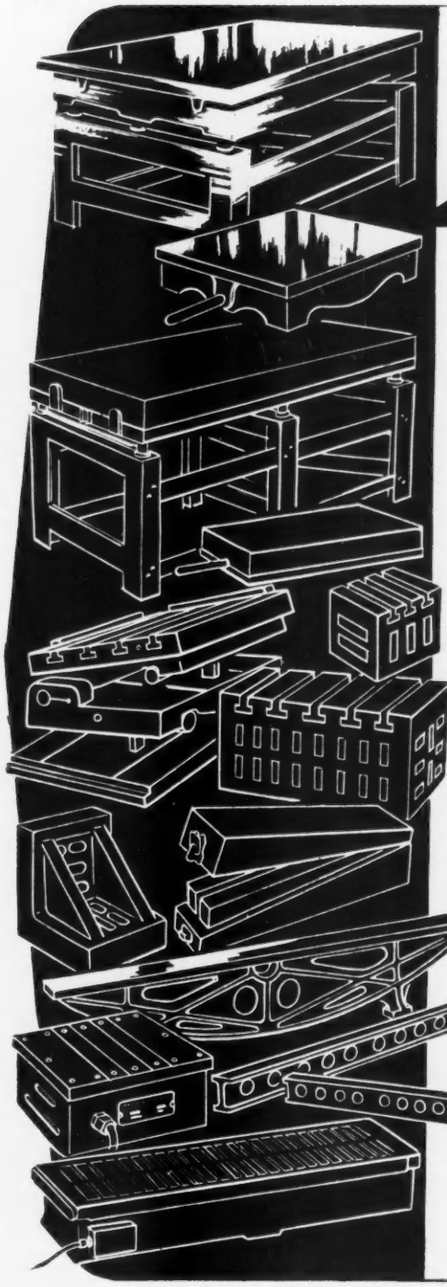

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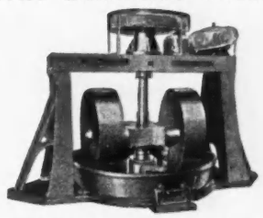

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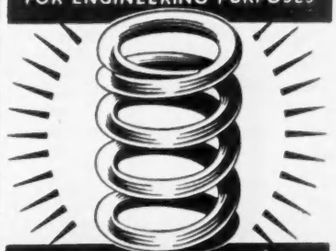

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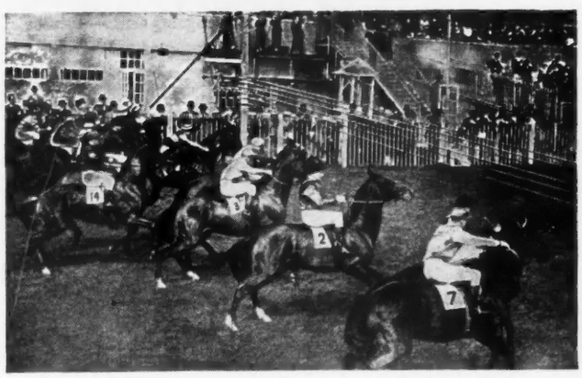

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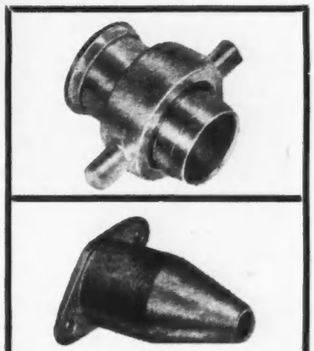

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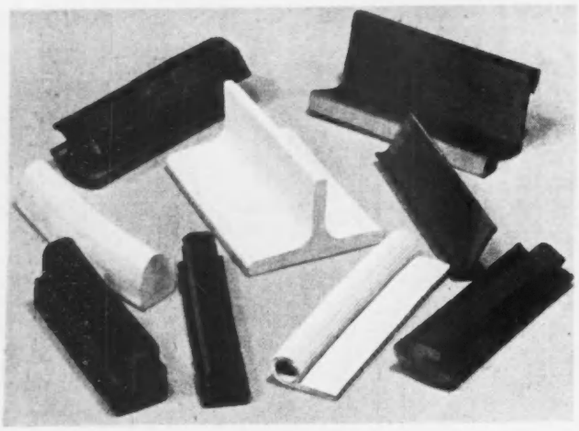

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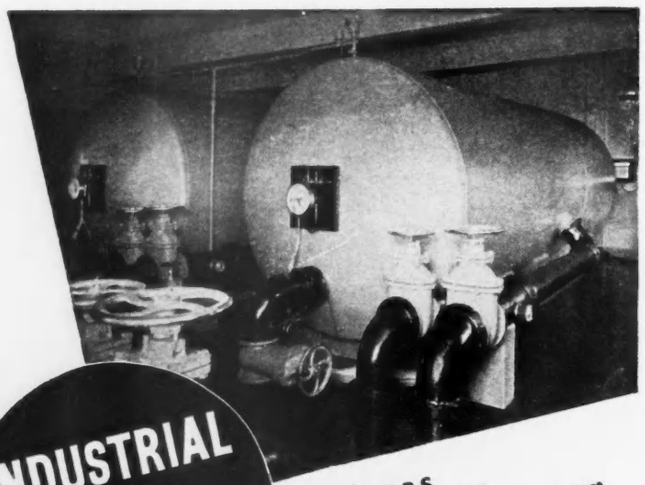

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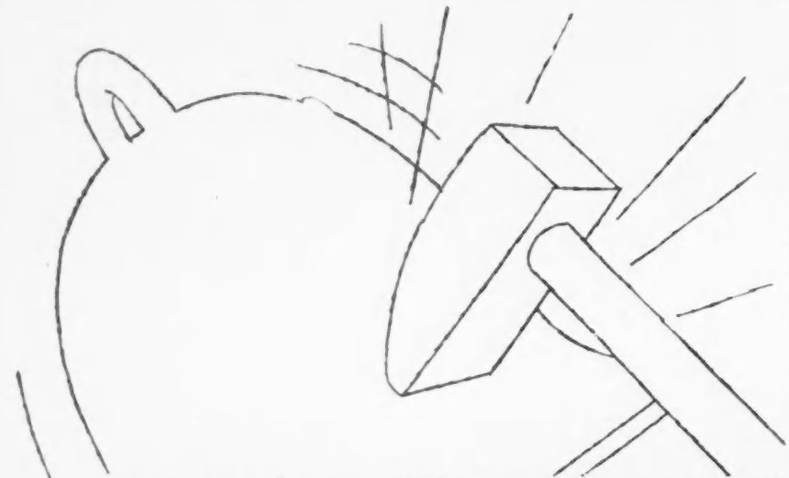

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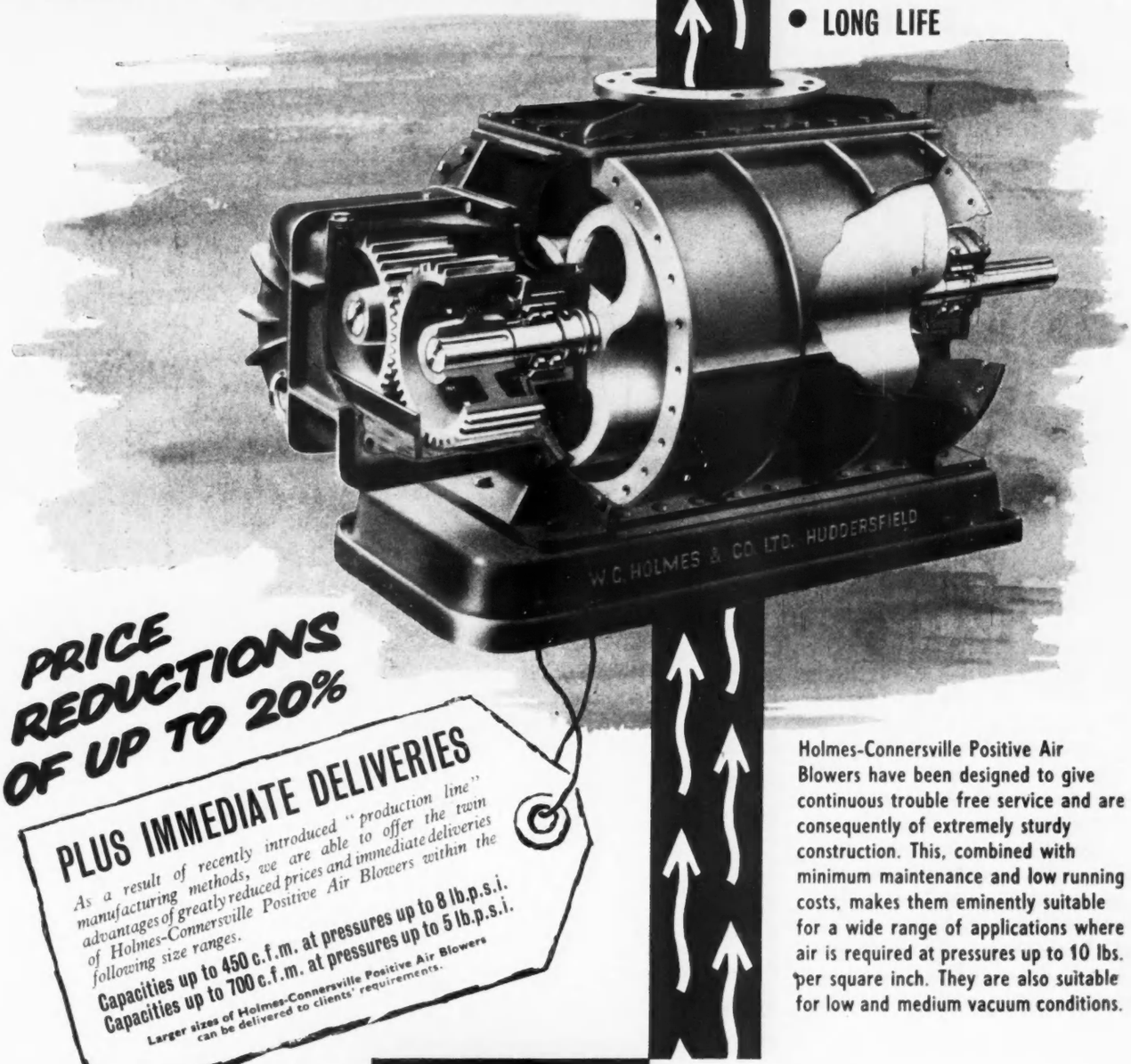

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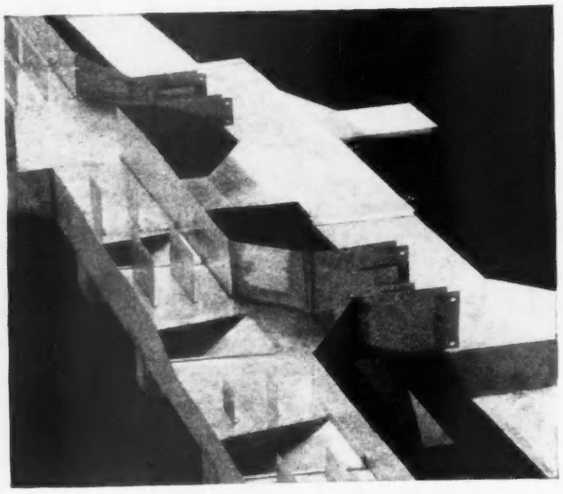

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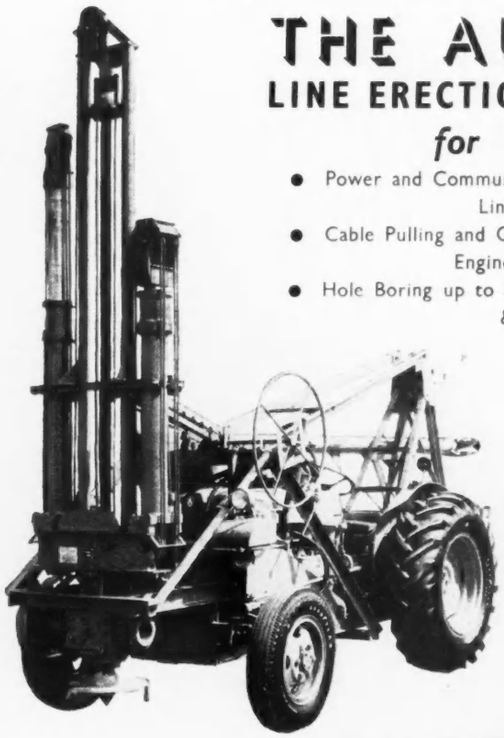

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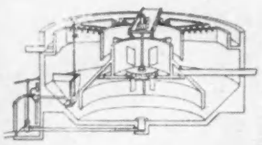

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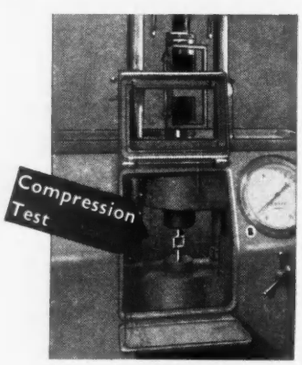

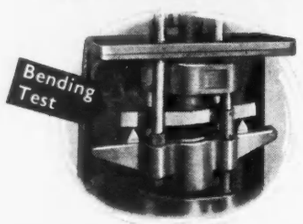

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THE ENGINEER

No. 5418 NOVEMBER 27, 1959 VOL. 208

WAGES AND HOURS

Full replies to union claims for increased wages and shorter hours for those employed in the shipbuilding and engineering industries have now been made by the appropriate employers' federations. The claims, which were submitted in September by the Confederation of Shipbuilding and Engineering Unions, were similar in detail. They were for a " substantial increase " in the present rates of wages and for a forty-hour week without loss of pay. In the discussion during the submission of the claims, the " substantial increase " was defined by the union confederation as £1 a week. The last wage increase, made just over a year ago, was one of about 4 per cent, bringing the basic minimum wage for a forty-four-hour week to £9 6s. 8d. for skilled men and £7 17s. 4d. for unskilled men. But average earnings have been above those figures, those of skilled fitters, for example, averaging, at the end of June, £12 13s. 1½d. a week for time-workers and £14 7s. 5½d. for payment-by-result workers. The gist of the unions' claim was that the proceeds of increased productivity justified a " substantial increase."

Both the Shipbuilding Employers' Federation and the Engineering and Allied Employers' National Federation have rejected the claims. The shipbuilding employers gave their reply just after our last issue had gone to press. Their principal argument—and it is a perfectly valid one—was that the outlook for British shipbuilding and ship repair work was so unfavourable that no effort must be spared to reduce prices. That could not be done, the Shipbuilding Employers' Federation declared, by increasing wages. On the claim for a shorter working week, the shipbuilding employers said that they would be quite willing to discuss with the unions the possibility of some reduction in hours as soon as there was concrete evidence that the unions were willing to co-operate in the introduction of new techniques and methods and in dealing with " such matters as loss of working hours, unnecessary double manning of machines, and restrictions on output."

The decision of the Engineering and Allied Employers' National Federation was conveyed to the unions on Tuesday at a meeting which lasted for five hours. The relevant statement is summarised on page 713. The engineering employers rejected the wage claim, making the point that, since 1954, earnings had risen about twice as much as production. They also said that the average time worked was still over forty-eight hours a week. As to a shorter working week, the employers' comment was that it was difficult to accept the unions' assumption that higher productivity would result. New plant, research and development and new techniques were all important factors in increased productivity. Productivity must continue to rise if the engineering industry was to maintain its competitive position. But the Federation expressed its readiness to negotiate with the unions for a reduction in the working week, with the proviso that any settlement as to hours must be accepted as a settlement of both claims. Before Tuesday's meeting ended, the Federation made an offer to reduce the working week from forty-four to forty-two-and-a-half hours. That offer, however, was not acceptable to the union representatives. The position is, therefore, that the matter will be considered early next month by the full executive of the Confederation of Shipbuilding and Engineering Unions, which will then, no doubt, seek further discussion with the employers. Meanwhile, the unions may realise more clearly that to concede a wage increase and a shorter working week simultaneously is not economically practicable.

BRITISH SHIPPING SURVEYED

A survey of British shipping entitled " The British Shipping Industry," recently published by the independent, non-party organisation known as P.E.P. (Political and Economic Planning) reviews the changing pattern of the maritime scene and gives facts relating to the world fleets of to-day. Statistics relating to the shifting emphasis of trade are brought to notice and details set out of the various shipping companies and comments made upon internal organisation and the effect of taxation. The place of British shipping in the industry of the country is shown by the fact that one in 275 of the population earns a living in merchant ships and that even in 1958, a year of depression, our ships earned £135 million in invisible exports. Capital represented by the fleet is quoted as £1200 million, with a replacement value of £3000 million. The steady decline of the British Commonwealth Merchant Fleet as a percentage of the world total from 43 per cent in 1914 to 30 per cent in 1939, to 27 per cent in 1948, and to 23 per cent in 1958, is underlined, as is the rise of Liberia as a maritime country. Attention is drawn to the fact that the Panhonlib, or flag-of-convenience fleets, now total about 16,000,000 tons gross. An examination of this situation as revealed by the survey is that 40 to 45 per cent of this total of these fleets is owned or controlled in the United States, which raises the active fleet of the United States from 9,000,000 to 16,000,000 tons gross. American money, it is contended, is invested in Norwegian, Greek and British fleets so that there is reason to believe that the United States occupies the major position in maritime affairs. Another table indicates the growth of the world's main fleets between 1914 and 1958 and between 1948 and 1958. The first column credits the United States with a 540 per cent increase, while the second records a 950 per cent increase for Germany, the respective figures for the United Kingdom being 105 and 112 per cent, a modest performance which highlights the rise of Japan, Norway and Italy, the Netherlands and others. A remarkable change in recent years is the rise in tanker tonnage which totalled 10,700,000 tons in 1938 and 33,600,000 tons in 1958, while dry cargo tonnage rose from 57,100,000 to 70,400,000 tons. These figures, it is pointed out, indicate that most of the post-war growth in trade can be credited to the movement of oil. Based on the figures quoted, it is concluded that Britain's position has declined, dry cargo and passenger ships being actually

less at 14,400,000 tons in 1958 than in 1938, when the figure was 15,100,000 tons. Nevertheless, shipping continues to play a major role in the country's economic affairs, and it is stated that the industry employs over 100,000 ashore and 142,000 Europeans, plus 44,000 Asians, afloat.

The peculiar problems facing the industry, particularly trade cycles, are shown by the fluctuation in profits, which is quoted as being twice the average for all industry during the years 1924 to 1935. Shipbuilding profits also fluctuated to a degree greatly in excess of other industries. It is noted that 8,000,000 tons of shipping is laid up, of which 1,000,000 tons is British, and this is coupled with increased world building capacity. Although the shipping depression is naturally of concern to British owners, it is commented that they are more concerned with the artificial support given by most nations to their shipping and the taxation levied on British owners from which their foreign competitors have been relieved. As regards artificial aid, the Americans, with their fifty-fifty rule, are stated to be the worst offenders, and the geographical application of this rule means that 60 per cent of the cargoes governed by the rule are carried in United States ships. Other points noted are that the United States Government pays about half the cost of a new ship and also provides operating subsidies on trade routes deemed to be essential. Furthermore, this American practice has encouraged other nations to adopt similar methods, as a result of which the United Kingdom has had occasion to make forty-seven formal protests in twenty-six foreign countries upon this question of discrimination. In the face of this position, one British owner is quoted as wishing to re-examine this old custom of the freedom of the seas, while others are stated to be not quite ready to restore the Navigation Laws. The present position with regard to taxation and replacement is set forth for a particular ship. The price in 1939 of a 9500-ton cargo vessel is quoted as £145,000 against a present-day replacement cost of £675,000 ; thus the owner has to find £530,000 which the 40 per cent investment allowance reduces to £260,000. This amount has to be found out of taxed profits so that the British owner is still at a disadvantage compared with a Panhonlib owner. The pamphlet, after deciding that there is no reason for nationalisation of the industry, concludes with a number of criticisms, such as that there are few university graduates employed and that the industry takes little advantage of management courses and of experience gained in other industries. The selling techniques of the shipping companies are labelled as primitive while the attitude to research is called backward, and the interest in nuclear power is questioned.

The survey is largely based upon figures issued by Lloyd's Register of Shipping, the Chamber of Shipping and other authoritative sources and, as stated in the preamble, is intended to give the general reader a balanced view of shipping problems. It would appear to be cold comfort to shipowners to advise that flags of convenience should be forgotten for after all it is a major point with shipowners that flag-of-convenience fleets pay practically no taxes, so that capital is readily available, out of untaxed earnings, with which to build new ships to expand the fleet. Whether an influx of university graduates and an expanded use of computers would really help the position of the industry as much as its critics assume is open to doubt, while the comment upon the reluctance of shipowners to adopt new ideas largely depends for its verity upon the value of such developments and whether they are adjudged to be of real economic advantage. The question of nuclear power is hardly one for an individual shipowner for, as the figures quoted in the survey show, taxation and other difficulties hardly encourage a shipowner to indulge in the luxury of venturing into the nuclear power field at present. This is especially so at a time when various systems are being assessed and consideration given to the installation of a nuclear power plant into a ship to gain experience. After all, the propulsion system must offer some advantage over current propulsion systems before a shipowner can be expected to show much practical interest. Whether present managerial efficiency can be compared with that of earlier generations is, of course, open to question. But in view of all the obstacles to be surmounted the fact that our shipping does obtain a good share of world trade is evidence of reasonable efficiency in the business of shipping. What does seem to emerge from the facts highlighted in the survey is that British shipping cannot continue to maintain its relative position in the world without direct Government action. Since a substantial fraction of the output of the engineering and allied industries of this country goes to the shipbuilding yards whose prosperity is largely now dependent on the prosperity of British shipping that is a conclusion which engineers should chew upon. Their interests as well as those of shipowners are involved.

AIRCRAFT-CARRIER " HERMES "

Laid down at Vickers-Armstrongs' Barrow shipyard in June, 1944, the aircraft-carrier " Hermes " was commissioned for service in the Royal Navy on November 25, nearly fifteen and a half years later (estimated building cost, £20,000,000.) Originally designed as a sister ship of the 22,000-ton " Centaur," " Bulwark " and " Albion "—which each cost only about £10,000,000—her completion was deliberately delayed to incorporate all the latest aids to naval flying developed during the past few years—the angled deck, steam catapult and deck-edge lift. The delay in her completion has also enabled her to be equipped with the new 3-D radar—already fitted in the reconstructed " Victorious "—which gives her an air detection and direction system unsurpassed in any other carrier in the world. Powered by Parsons geared steam turbines, she has a speed of 28 knots and though only able to operate about half the number of the aircraft carried by the 43,340-ton " Ark Royal " and " Eagle," she is, in fact, little inferior to these larger carriers operationally. Early in the new year she will embark her complement of aircraft. These will include the new single-seat twin-jet strike fighter " Scimitar " ; the two-seat day and night all-weather fighter " Sea Vixen," equipped with " Firestreak " air-to-air missiles ; Westland " Whirlwind " anti-submarine helicopters and Fairey " Gannet " airborne early-warning aircraft. With the replacement of fixed wing aircraft by helicopters for anti-submarine work, it is very satisfactory that other employment has been found for the later and improved versions of the anti-submarine Fairey " Gannet."

The " Hermes " is 741ft 6in in length and has a beam of 144ft 6in, with an armament of ten 40mm A.A. guns in twin mountings, all radar controlled. Her boiler-room and engine-room equipment is remote-controlled and the ship is so designed that the personnel within the " citadel " area can be isolated while she is proceeding through atomic fall-out. A liquid oxygen plant has been installed for supplying high altitude flyers and the ship is air conditioned to enable her to operate at peak efficiency in any part of the world. The accommodation provided for her complement of 189 officers and 1643 ratings compares very favourably with that in any other large

warship. The crew have well-lit messes with comfortable bunks which can be collapsed during the day time to ensure the maximum recreational space. Food is served in dining halls and there are plenty of bathrooms and showers, a modern laundry and a well-stocked library.

There seems no solid foundation for the reports that the "Hermes" is likely to be the last carrier for the Royal Navy. The most probable wars Britain may have to face in the future are those of a limited nature overseas and the vital part which carriers play in providing air cover and close support for the Army was well illustrated in the Korean and Suez campaigns. Moreover, unless it is to be assumed that nations will commit suicide by waging war with thermonuclear weapons, it is clear from the Pacific operations in World War II that the carrier has greatly extended the striking power of maritime forces. There is indeed little doubt that she will continue to be the core of the Fleet for many years. Guided missiles are special-purpose weapons. There is no substitute for the versatility of the piloted aircraft as a general purpose weapon for attacking the great variety of fixed and moving airborne, seaborne and ground targets in maritime warfare. Only the trained pilot on the spot can make the prompt evaluation and decision necessary for selecting targets in a fast-moving situation. The carrier is the one naval vessel usable alternately or simultaneously against submarines and their bases and aircraft and their airfields and for the support of amphibious, land and air operations.

SAFETY ON THE SITE

There has just been brought to our notice a report of a recent meeting of the London Building and Civil Engineering Contractors Accident Prevention Group, at which Mr. G. H. Stuart Price presented a paper. His subject was "The Cost of Safety and the Cost of Accidents." He attempted to weigh the cost of safety and contrast it with the cost of accidents ; and his remarks, of course, related only to his experience at building sites. In fact, however, much of what he had to say applies with equal force to engineering factories. He remarked, for example, that an accident "dislocates working routine." Anyone who has been in a factory when an accident has occurred will appreciate that point. For, if the accident is a serious one, a whole shop will stop work for some considerable time and for hours afterwards the event will be a subject for discussion, comment, and, usually, criticism of the management. Even if it is quite slight, there is often substantial dislocation because the injured person and the man in charge of the first-aid box both have to stop work or it may be desirable to detail someone to accompany the injured man to the sick bay lest he should faint on the way. Moreover, we have ourselves seen a whole shop stop work when a particularly well-liked young apprentice suffered a not very serious cut. Even the merest scratch holds up production in one way or another, if only by slowing down the rate at which a man works ; anything more serious may involve the making of telephone calls, use of first-aid materials, &c., and, unless the firm is unwise, a site investigation by some member of the staff charged with safety. Last but not least (a matter a legal contributor to our columns discusses on page 676), there may be heavy financial claims to meet. Mr. Price pointed out that for every "reportable" accident there are likely to be at least fifty accidents that go unreported. We are not the least surprised by the figure he quoted for the cost of an unreported accident of £10 a time on the average.

Mr. Price's precepts for avoiding accidents apply just as well to engineering works as to the building sites, to which he in fact referred. They are that supervision shall be good, that the site shall be kept tidy, and that there shall be adequate safety equipment in good order and men trained in its use and in safety precautions. The last of those desiderata requires that men shall be sent out to training courses. The main reason for trying to prevent accidents is, of course, humanitarian. But Mr. Price brought out the point—one that we have often stressed ourselves—that in the matter of safety, humanity and economy go hand-in-hand. It really saves money to spend money on accident prevention !

TECHNICAL CONTRIBUTORS SECTION

In this issue there will be found a sixteen-page section entitled "Technical Contributors Section" and dated November, 1959. In future it is our intention to include such a section in the last issue of every month. The number of pages devoted to the section will vary between eight and sixteen. The reason for this new departure is that, partly as a consequence of the dispute in the printing industry some months ago, which very substantially reduced the number of pages we could publish for several successive weeks, stocks of contributed articles in hand and awaiting publication expanded. We hope by publishing the new section somewhat to reduce the delay between the acceptance of an article and the date of publication. We also hope it will eventually become possible to provide authors with some advance information about the date of publication of their articles.

Not all contributed articles will be contained in the new section. Articles published in the section will be those of a more specialised character or highly mathematical or analytical in nature. Contributed articles of wider general interest, such, for example, as that on "Some Locomotives of 1909" by E. C. Poultney, which appears in this issue immediately following the new section, will continue to be published, as and when convenient or timely, in the main body of the paper.

The Engineer—100 Years Ago (NOVEMBER 25, 1859)

"AGRICULTURAL MACHINERY"

"Whether the establishment of the Agricultural Engineers' Company will have a decisive influence in hastening the general introduction of machinery in agriculture, time only can show. Competing manufacturers would be by no means likely to associate themselves, unless with the prospect of increasing their sales collectively, and in doing so they would, of course, aid in the great revolution now going on in what has always been and always will be the most important branch of industry in the world. Steam cultivation is making constant progress ; and, if no unexpected triumphs have been achieved in its application during the past season, the publications of the Patent Office show that those who are best able to make fresh improvements have not been idle.

"Besides the deep trenching which steam ploughing secures, and besides doing its work cheaper and more effectively, it is always under command, and five or six acres can be ploughed daily in weather when no horses could keep the ground. . . . . Like the introduction of machinery into other departments of industry, steam cultivation is likely to open fresh demands for labour. Not only will more land be brought under cultivation, but the product of a given acreage will be increased, and the preparation of crops for market, and other contingent work, is likely to require more agricultural labourers than are now employed."

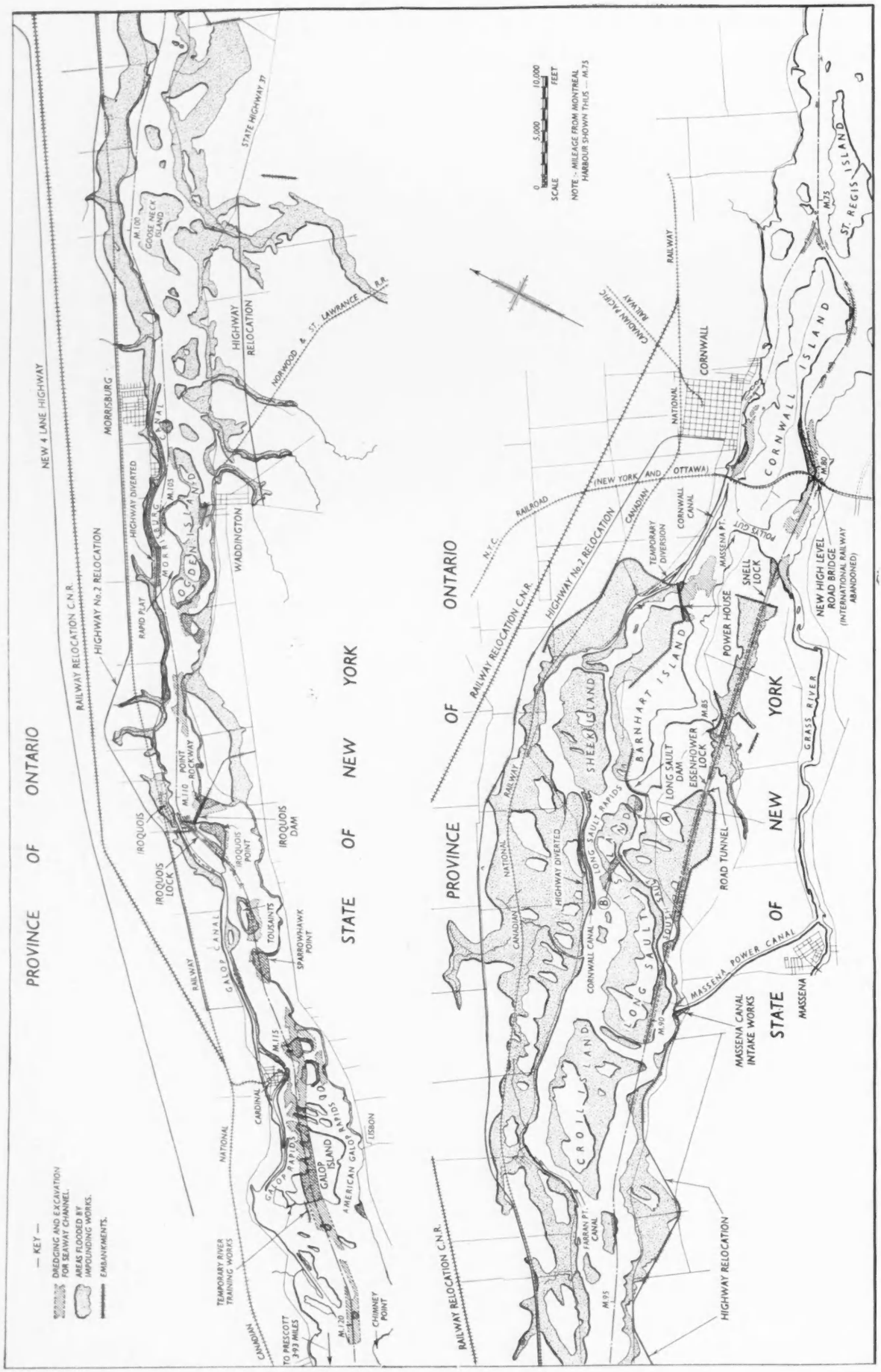
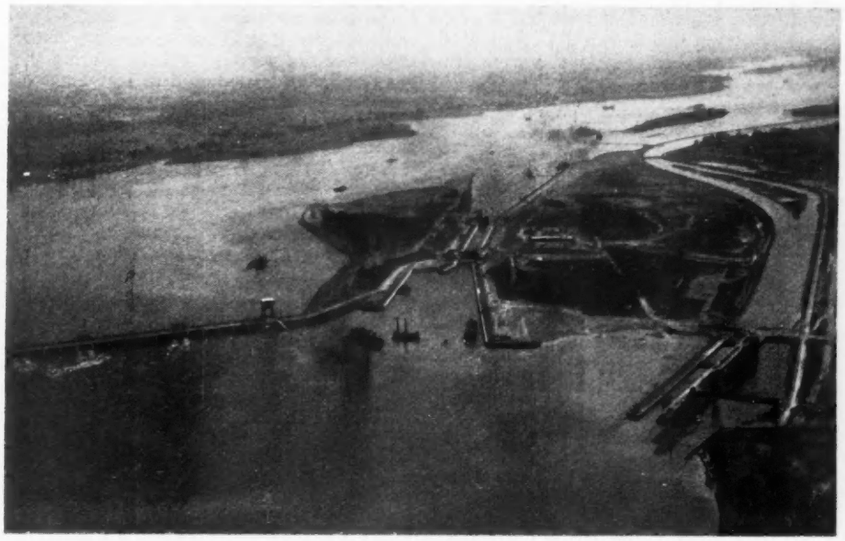


Fig. 31—The International Rapids section of the St. Lawrence River, showing the extent of the "power pool" and the principal engineering works in the power and navigation schemes

St. Lawrence River Development

IX—International Rapids*

During the summer, the "all-Canadian" section of the St. Lawrence Seaway was described in this journal in a series of articles. Here we describe the engineering works in the International Rapids section of the St. Lawrence River. They include the St. Lawrence River generating station—a major new source of power—and a concrete dam—the Long Sault dam. These two structures, together with flanking embankments, impound the river at Cornwall. Further upstream, the river is again controlled by a dam at Iroquois. There are locks at both these points, and a 10-mile length of canal at the former.



UP to the present we have described in this series the all-Canadian portion of the St. Lawrence Seaway and the power scheme at Beauharnois in the province of Quebec. We now come to the largest and most costly group of constructional works in the combined power and Seaway scheme, which are situated along a 44-mile length of the St. Lawrence where it forms the boundary between the U.S.A. and Canada. The International Rapids section, as this part of the scheme is called, includes three locks, two dams, the two adjoining national sections of the St. Lawrence generating station, vast quantities of dredging and earthworks, including a length of 10 miles of navigation canal, very extensive re-routing of roads and railways, including two new bridges, and the rehousing of 6500 people.

It is not our intention to repeat here some of the more general facts about the hydrology and geology of this length of the river. These will be found in the general survey in Part I, together with figures of constructional quantities for some of the works just enumerated. It may be recalled, however, that the works here are the joint responsibility of the two nations, and are being carried out under the direction of four agencies, viz., the St. Lawrence Seaway Authority and the St. Lawrence Seaway Development Corporation (respectively the Canadian and U.S. agencies for the navigational works) and the Hydro-Electric Power Commission of Ontario and the Power Authority of the State of New York (similarly the Canadian and U.S. agencies for the hydro-electric development).

An understanding of the whole area can be gained from perusal of Fig. 31, which shows the principal works and the areas flooded by the "power pool" formed by the impounding works. The "power dam" lies between Barnhart Island and the Canadian shore. The channel to the south of Barnhart Island has been impounded by Long Sault dam, which is a spillway dam with crest gates of capacity adequate to discharge the greatest river flows. The navigation channel has been taken to the south side, in U.S. territory, where the power station head is taken up by two locks, separated by a length of canal, and approached by newly-constructed channels both upstream and downstream.

At the upstream end of the power pool, about 28 miles from the power station, is Iroquois dam, a gated structure across which a small head is normally maintained. A navigation channel has been cut on the Canadian side at this point and the Iroquois lock built in it. The river level upstream from the structures at Iroquois is substantially that of Lake Ontario. The map shows the extensive nature of the dredging and excavation over the next few miles, particularly at Galop Island. Apart from dredging and excavation, however, there are no other engineering works upstream from Iroquois until the Welland Ship Canal is reached after the journey through the 68 miles of the Thousand Island section and then across Lake Ontario.

River Control

All of the power developments on the St. Lawrence River are essentially run-of-river schemes which profit by the river's remarkable regularity. At this section of the Seaway and power scheme, however, a measure of control has been introduced which, as would be expected in a major scheme of this kind, is a compromise between the interests of power, navigation and flood control. The storage available in Lake Ontario is utilised, under international direction, by control at Iroquois barrage to achieve several principal aims as follows: (*a*) during the navigation season, minimum flow will be maintained at 180,000 cusecs, i.e. river levels at certain critical points will never be less than have been experienced over the past ninety-six years since records have been kept, and a stipulated minimum level will be maintained at Montreal harbour; (*b*) as much power as possible, consistent with other aims, will be generated during the autumn and winter—a dependable flow of 205,000 cusecs will be maintained throughout the autumn and winter; (*c*) the range of levels in Lake Ontario will be limited for the benefit of lake shore interests, and in particular, a maximum level of 248ft above sea level will not be exceeded nor the lake allowed to fall below a minimum level of 244ft; (*d*) in the day-to-day operation of the scheme, abnormal conditions, for instance in the spring thaw when ice jams cause flooding, or when the Ottawa River is in flood, will be alleviated by regulating the discharges at Iroquois.

The mean river flow is 241,000 cusecs (see Table I, Part I). The maximum flow which will be discharged from Iroquois barrage is 310,000 cusecs, and the ratio of extreme flows has been reduced from 2 to 1·7. The figures quoted are for "mean monthly flow," and the design of the regulation system allowed for short-term variations from the monthly mean figures. In design, these flows were "routed" through the river system, as modified by the new works, to determine "minimum water surface profiles," either by computation or by use of hydraulic models.

In its natural state, Lake Ontario experienced an annual variation in level of about 6ft which, as noted above, has now been reduced to 4ft. The storage in the lake corresponding to a change in level of 4ft is nearly 20,000,000 acre-feet. The mean flow of the river, by comparison, is equal to about 500,000 acre-feet in a day. Local changes in level of a foot or two occur in the lake due to wind or barometric changes, and can cause surges in the river, and the control system will reduce the peaks of phenomena such as these surges in the day-to-day operational procedure. Immediate control of power generation is available in the power pool, but no range of levels in the pool for storage is available under the International Joint Commission's directive.

In its natural state, the river flow was controlled in this region by the Galop Rapids which were in effect a dam at the outlet from Lake Ontario. The river flow downstream of the rapids was thus directly dependent on the level of Lake Ontario except when ice was present above the rapids. These rapids have now been excavated and replaced as a control of lake level by Iroquois barrage. Apart from normal control of flow as just explained, the barrage also has one other important control function, in that it is operated to reduce the flow to the power station in the critical period in the early winter when ice is forming, thus allowing a protective sheet of ice to be formed

* Parts I—VIII appeared May 29—July 17.

across the power pool as early as possible. Subsequently, the barrage is operated to maintain this ice sheet throughout the winter. The barrage was also important in regulating the river during the later stages of construction of the power house and dam downstream, when natural river levels were always closely maintained. During this period the head across it was nearly 25ft.

Hydraulic Design

The magnitude of the constructional works in the International Rapids section of the St. Lawrence gave rise in the early stages to correspondingly large efforts in hydraulic studies, and to the construction of a series of large fixed-bed models.

The method of backwater computation employed to relate head pond levels at the power house to levels in Lake Ontario was described in two papers presented at the annual conference of the Engineering Institute of Canada held last June in Toronto, amongst a group of eight papers on the St. Lawrence Seaway and power schemes. The backwater computations were based on an adaptation of the Chezy-Manning equation, arranged for solution by a digital computer. For an account of this work we would refer the reader to those two papers, namely, "Backwater Computations for the St. Lawrence Power Project. Part A. Hydraulic Engineering Aspects of Computations," by H. M. McFarlane, and "Part B. Backwater Calculations on the Ferranti Digital Computer," by C. C. Gotlieb.

The main aims behind the model studies may be enumerated to give an overall idea of the scope and intent of this work.

The first aim was to verify that the basic design criteria would be achieved. We have already noted that control of river flow was related to minimum acceptable water levels at various points along the river; the control scheme thus needed extensive model testing before it could be worked out in detail. In addition, the basic requirements were that in all navigation channels flow velocity should not exceed 4ft per second, and in critical areas for power generation such as the power station head pond, the corresponding maximum velocity had to be reduced to 2·5ft per second, during the period when ice forms. This velocity allows a sheet of ice to form rapidly, which is necessary for successful winter operation. A higher velocity carries pieces of ice under the end of the ice sheet already formed, and they then tend to collect and freeze into a "hanging dam."

Apart from checking these basic criteria, the hydraulic models were also used to develop the most economical plans for works such as channel improvement, thus keeping excavation and dredging to a minimum and positioning training banks advantageously. Then the hydraulic effects of temporary works such as coffer dams were studied, and alternative schemes of construction—as submitted in the various tenders, for instance—were compared. This work ensured that the characteristics of the river were not seriously affected during the constructional period. Another class of tests aimed at giving information for the design of specific structures such as a lock gate or the scroll casings for the power house. Examples of hydraulic design of locks have already been given in earlier parts of this series.

Three large models were built by Ontario Hydro in that organisation's laboratory at Islington (Ontario), to cover the "power pool" area of the new developments. Each of these models was built to a scale of 1 to 500 horizontally and 1 to 100 vertically (the time scale was 1 to 50, and velocity 1 to 10). The first of them covered the Galop Rapids reach of the river, and extended over a prototype distance of about 16 miles, from Prescott down past the Galop Rapids and Iroquois barrage to Waddington. The second covered about 8 miles, the Ogden Island reach, from just below Iroquois barrage down to Morrisburg. And the third, the Long Sault Rapids reach from Croil Island at the upstream, down through the area where the river was diverted and the power house area dewatered, to the downstream side of the power house.

This last model was the largest of the three, extending over an area of 146ft by 40ft. Its main purpose was to study the various stages of river diversion and closure involved in constructing the main structures within this area. By contrast there are no structures in the region which was reproduced in the second model. The investigations carried out with it sought to balance the needs of channel excavation for navigation and for power, investigate flow distribution around Ogden Island, find areas for dumping spoil, and the effects of the various works on water levels in the area, particularly so that the 14ft navigation would not be interrupted before "pool raising." Investigations on the first model were generally similar in character; the area included the critical length of the Galop Rapids where very extensive excavation was needed. The ice-forming criterion for velocity governed the reach just above Iroquois barrage, and the effect of the barrage and its operation on levels at the approach channel and lock at Iroquois were also investigated.

A fourth model, covering the Cornwall Island reach (i.e. from the downstream side of the power house down to past St. Regis Island) was built for the Seaway Development Corporation at the U.S. Corps of Engineers laboratory at Vicksburg, with horizontal and vertical scales respectively of 1 to 300 and 1 to 100. Again the aims of the tests were broadly similar, and the hydraulic conditions in the South Cornwall channel where navigation enters the U.S. Seaway, and in the power station tail-race, were examined.

An undistorted model covering the length from Massena Point to the middle of Cornwall Island was also built at Vicksburg. Its scale was 1 to 100, and its purpose was to study the rock embankments needed in the channel called Pollys' Gut, where cross currents of high velocity are experienced. The whole series of models was completed by another model of the Cornwall Island Reach built for the Seaway Authority by the National Research Council at Ottawa, to carry out complementary investigations for this area for both power and navigation.

Models for the design of hydraulic structures in the International Rapids section included an investigation of the guard gate at Eisenhower lock, and tests to evolve the design of the filling and emptying system for the two U.S. locks by the U.S. Corps of Engineers. Ontario Hydro's design studies included tests with a 1/80 scale model of Long Sault dam, 52ft long, with which the energy-dissipating characteristics of the Spillway and hydraulic aspects of constructional sequences were investigated, a similar model of Iroquois barrage, and a 1/60 scale model of the Massena intake. This last model represented new headworks for the Massena canal on the U.S. side. Although the power station associated with this canal was superseded when the "power pool" was formed, the canal still has water supply functions to fulfil, and hence intake works had to be built.

A large-scale model—at 1 to 36 scale—was built of a typical turbine hydraulic layout, with intake, scroll casing and draft tube. This model was in transparent plastics and was used to assess flow conditions generally and hydraulic loads on the three head gates associated with each turbine. A similar model was made of the drum-gated ice weirs at the power house.

Iroquois Barrage

The heading illustration shows that part of the Iroquois barrage which abuts on the Canadian side of the river, and next to it, the Iroquois lock and the new cut in which the lock was constructed. To the right can be seen one of the locks of the 14ft navigation, now superseded. Quite detailed information on the Canadian locks of the Seaway has already been given in earlier parts of this

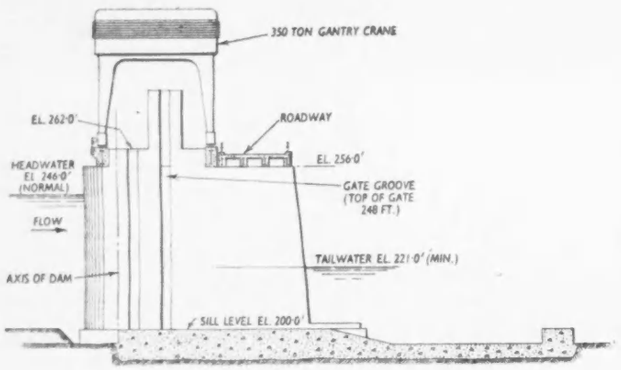


Fig. 32—Typical section through sluiceway, Iroquois dam

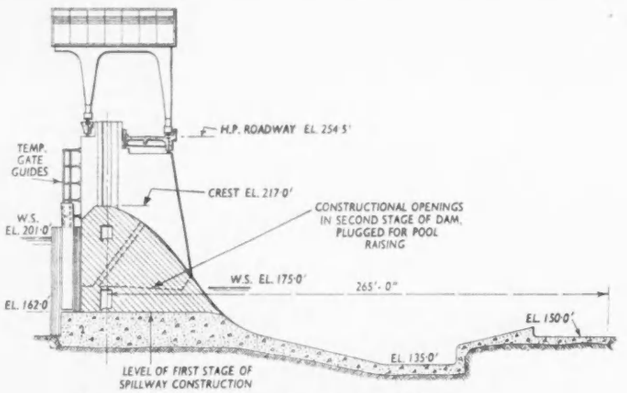


Fig. 33—Typical section through Long Sault dam

series, so description here is limited to the barrage, which was constructed by the U.S., but is operated by the Canadian, power agency.

There are thirty-two sluiceways in the Iroquois barrage, each 50ft wide, and each closed by a sluice gate 50ft wide by 48ft high, as shown in the cross-sectional drawing, Fig. 32. The head across the barrage is normally about 6in to 1ft, but may increase to a maximum of about 5ft or 6ft in normal operating conditions. However, design was governed by a head of about 24ft experienced during the period of construction. With the completion of the dam, the level upstream of it was raised to help dredging, but the level downstream remained at its natural value until the power pool was flooded. Before the project was started, the river level at Iroquois was about 220ft (above sea level):

Fig. 34—An early stage in the construction of Long Sault dam. The first stage of construction has been completed and the river flow is passing through the completed section of the dam. The temporary channel upstream of this section has been plugged and the downstream cofferdam closed across the main channel, where the dam is to be built in the second stage

now the power pool is maintained between levels of 238ft and 242ft and the river upstream from the barrage (i.e. Lake Ontario) between 244ft and 248ft.

The first section of the barrage was constructed " in the dry," inside the old shoreline on the U.S. side of the river. Fifteen of the sluiceways were completed in this way and excavation completed within the cover of embankments, more or less following the original shore of the river. Then the embankments were dug away and river flow was allowed to pass through the newly-completed section of the barrage. At the same time a cofferdam was built to close the original river channel and allow the second stage of the barrage to be built. This cofferdam was built as a cellular steel-sheet-piled enclosure, starting from the end of the completed work. A " finger dyke " was built out into the river ahead of the other works, to slow down the flow in the region where the steel-piled cells were being built. The barrage has a total length of 2335ft.

The gates are vertical roller-gates handled by two 350-ton rail-mounted gantries. The gates will often be completely submerged with normal operating conditions. They are double-skinned gates, and can be heated in the winter. Manufacture of the gates was generally similar to the manufacture of the mitre gates for the Canadian locks. Large gate elements each 6ft by 12ft by 50ft in size and weighing about 40 tons, were shop-fabricated and brought to the site by rail, after a trial shop assembly of each complete gate. Site assembly was by welding, following a strict sequence which avoided distortion, since the final machining and adjustment of gate wheels and fitting of the seals had already been completed to close tolerances at the time of the shop assembly.

The cost of the various contracts for Iroquois barrage was over 17,000,000 dollars. The main contractor was a consortium of U.S. firms known as Kiewit-Johnson-Johnson. The gates were made by Canadian Vickers, Ltd. The canal and lock at Iroquois were built to the designs of the Canadian agency—the Seaway Authority—by the Pentagon Construction Company, Ltd., and Iroquois Constructors, Ltd. During the latter stage of construction, after completion of Iroquois barrage and prior to flooding the power pool, the head across the lock was 23·5ft. The sector gates were successfully operated against this head, for the Iroquois lock had already superseded the stretch of 14ft navigation at Iroquois, and was in use during this period. Part III of this series gave further information on this abnormal gate performance.

Long Sault Dam

Long Sault dam is a structure similar in function to the Iroquois dam. But a glance at the sectional drawing (Fig. 33), will show that the head across the spillway of the dam is appreciably greater than at Iroquois (and is, of course, equal to the power station head) so that design of the dam and the spillway bucket is correspondingly more elaborate.

Reference to the map clearly indicates the Long Sault dam's function in the whole project. During construction the natural river level was closely maintained, for two reasons, namely (1) to keep the 14ft canals in use throughout the whole period, and (2) to keep in use the Massena hydro-electric station on the U.S.A. side, which had no headworks, and could not therefore tolerate any substantial changes in river level.

The original river channels are indicated on the map. The most northerly, serving the Cornwall Canal, remained unaffected. The next one was dammed between Sheek Island and Barnhart Island, to allow construction of the power house. Thus virtually all the river flow passed through the Long Sault rapids or the South Sault channel. The existence of these two channels allowed construction of the dam to be carried out in two stages, rather like the work at Iroquois.

In the first stage, the South Sault was cofferdammed with two cellular steel-piled dams, and a temporary cut was made (marked *A* in Fig. 31) to divert the flow from the South Sault channel. Then, that section of the dam between the U.S. river bank and Long Sault island was constructed, comprising thirteen of the spillway openings. At this stage, however, although the spillway piers were built to the full height, the spillway openings themselves were built only to a level 55ft below the finished crest (i.e. to about stream bed level) so that it would be possible to pass the whole river flow through them in the next constructional stage.

The second stage involved the construction of a cofferdam across the Long Sault channel, close to the rapids. This cofferdam was the most critical amongst all the St. Lawrence cofferdams, for under natural conditions only 10 per cent of the flow went through the South Sault channel and consequently almost the full flow of the river at a fast flowing site had to be contended with. The scheme adopted called for a cut 600ft wide (marked *B* in Fig. 31) through Long Sault island, and the construction of a rock-fill cofferdam just below it across the main channel ; that is, the cofferdam was just upstream of the rapids. The new cut was dammed off until the appropriate stage of cofferdam construction had been reached (as indicated by model tests) and a training bank was built from Long Sault island to maintain levels in the Cornwall Canal.

As dumping of rock-fill continued, so flow velocities in the river increased, and before the final closure the size of the dumped rock was progressively increased up to 4- to 6-ton stones which were placed in the final gap. Eventually, 2½-ton stones were being swept downstream, and at the last stage frames of timber and steel were placed in the gap and held by cables, while quarry-run rock was rapidly dumped for a few hours to complete the closure.

At this stage seepage through the rock bank was estimated to be 10,000 cusecs. Till was then dumped on the upstream face, to seal the cofferdam. The total quantity of material used for this cofferdam was about 205,000 cubic yards, the base width of the cofferdam being over 200ft and its height about 70ft. Flow velocities were about 7ft to 10ft per second in Long Sault channel in nature ; maximum velocities of 7ft to 14ft per second were experienced over the crest of the dumped rock after the first stage of dumping, and up to 17ft per second at the crest, and 28ft per second at the tail water, through the final 100ft gap. Fuller details of this cofferdam may be found in an article by J. V. Danys in *The Engineering Journal* of September, 1958. The downstream cofferdam, and the Long Sault channel, isolated but still with water in it, are shown in Fig. 34.

Construction of the second stage of the dam, comprising the remaining seventeen spillway passes plus a length of gravity wall, then proceeded in the dewatered Long Sault channel. This time the spillway openings were built to the full height, but two temporary openings, each 16ft by 18ft were left in each spillway pass. Finally the river was diverted through these openings, the stage 1 spillway passes built up to their finished level, and the stage 2 openings closed at "pool raising" and afterwards concreted. Sections of the spillway gates were used temporarily to control the flow through these constructional openings.

The dam is 2250ft in length, and is curved in plan, which gives it a pleasing appearance. The spillway gates are thirty in number, each one being 52ft wide by 30ft in height. There are two 275-ton gantries which travel along the crest of the dam to handle the gates, but the central eighteen gates can also be operated from fixed gate hoists. The normal pool level now that the power house is in operation is 242ft.

As at Iroquois, the design of Long Sault dam contains no really novel or unorthodox features, but the magnitude of this structure should not be overlooked. It contains around 700,000 cubic yards of concrete, and the contracts placed for its construction totalled over 37,000,000 dollars. The main contractor was again a consortium, in this case of six U.S. contracting firms, namely the Perini Corporation, the Walsh Construction Company and the Morrison-Knudson, Kiewit and Utah Construction Companies. As with the Iroquois dam, the Power Authority of the State of New York was the agency building the dam, design and supervision being in the hands of the consulting engineers, Messrs. Uhl, Hall and Rich.

(To be continued)

Semiconductor Factory at Stockport

Semiconductor devices are now being produced at a rate of 120,000 *per week by The General Electric Company, Ltd., of England. About* 70,000 *transistors and diodes (over* 100 *types) are made weekly in the G.E.C. factory at Hazel Grove, Stockport, Cheshire, where the company has the headquarters of its semiconductor division. The remainder of the output, about* 50,000 *diodes* (30 *types) per week comes from the company's radio works, Coventry. Because of its manufacturing methods the group has achieved a very low reject rate and the average yield of all its products is stated to be between* 70 *and* 80 *per cent and in the case of one particular device,* 90 *per cent. A few of the special processes used by the company are described below.*

EARLIER this month we made a short tour of the Hazel Grove factory, Stockport, Cheshire, which is the headquarters of the semiconductor division of The General Electric Company, Ltd. This factory was started in April, 1956, but the company's interest in semiconductors is of much longer standing and a brief reference to the historical background may help to give perspective to the development of this project.

It should be recalled that the G.E.C. has been actively concerned with the use and manufacture of semiconductor devices since early days of the "cat's whisker" crystal detectors of the 1920s. For many years most of the company's work on semiconductors was concentrated in its research laboratories at Wembley. During the 1939–45 war these activities were expanded to meet the needs of the Services and hundreds of thousands of v.h.f. silicon crystal diodes were made for use in radar and telecommunications equipments. Then in 1945 a plant was established in the research laboratories to produce germanium crystals suitable for semiconductor devices. Soon afterwards factory production of germanium point-contact signal diodes was begun at the G.E.C. radio works, Coventry. To carry out the company's expanding research programme on semiconductors new facilities were provided in the Wembley laboratories in 1952, as described in THE ENGINEER, September 3, 1954, page 321.

This view of part of the Hazel Grove factory floor shows some of the transistor assembly lines

In April, 1956, a new factory was opened at Hazel Grove. There processes were developed and assembly lines laid out for the large scale production of a variety of semiconductor devices. To co-ordinate the company's effort in this field the semiconductor division was formed in 1958, with its headquarters and marketing organisation in Hazel Grove.

Production at the factory has been built up to the point where the weekly output is about 70,000 units. The factory turns out more than 100 types of semiconductor products, including low-power audio-frequency and radio-frequency transistors and a range of power transistors with ratings of 8A and 12A for use in audio output stages, d.c. converters and series stabilisers; low-power silicon junction diodes; and medium-power silicon junction rectifiers, diffused junction silicon rectifiers and germanium junction rectifiers.

Setting up an audio-transistor for final sealing of the can by cold welding with the application of a pressure of 90 lb per square inch in an inert atmosphere and at room temperature

SOME G.E.C. SEMICONDUCTOR PRODUCTS

The silicon junction diodes are specially suitable for operation at high temperatures (150 deg. Cent.). The range includes two high-speed switching diodes with recovery times of 0·12 microsecond (time for current to drop from 10mA to 0·1mA with −30V pulse applied, loop impedance of 2 kilohms); they are suitable for an ambient temperature of 100 deg. Cent. There is also a series of silicon zener diodes for use as voltage stabilising, clamping and reference devices.

Silicon rectifier diodes are made in three ranges, covering outputs of 0–300mA, 300mA–1A and 1A–8A respectively, finned stacks being used for the higher ratings.

In the range of radar mixer diodes there is a silicon Q-band mixer and a germanium X-band mixer with a very low noise factor.

An interesting point about the audio transistors is that the base mount is connected to the can—an arrangement which gives good thermal properties, with a maximum junction temperature of 85 deg. Cent., and correspondingly high dissipation ratings, which can be further increased in certain instances by mounting the transistor in a small cooling fin; the alpha cut-off frequency is 1 Mc/s. There is also a low-noise transistor, the GET 106 designed to suit pre-amplifier stages.

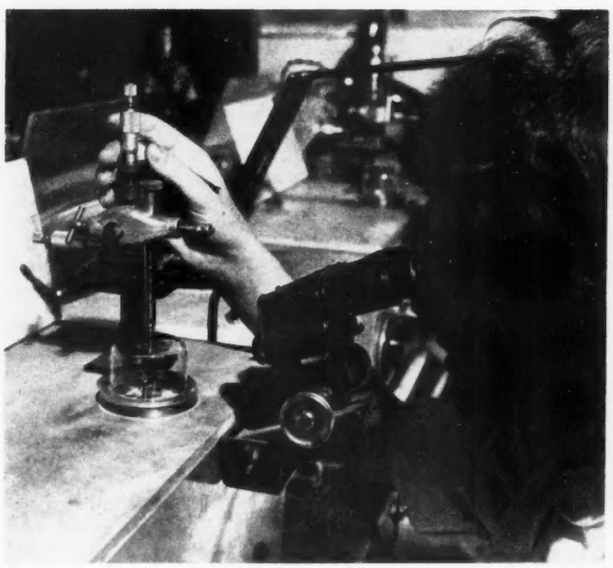
The switching and r.f. transistors include

an h.f. amplifier drift transistor.

A general view of the Hazel Grove production lines is illustrated above. Without attempting to describe the whole sequence of operations involved in transistor manufacture we shall deal briefly with a few of the special processes which the G.E.C. has introduced.

While Hazel Grove is largely self-contained as a manufacturing entity the germanium and silicon crystals themselves are grown at Wembley by a unit which is responsible to the production manager at Hazel Grove. These large crystals made at Wembley are cut into "dice" by a new method, known as diamond scribing, which is being introduced into the Hazel Grove factory, and is twelve times as fast as the saw-cutting method used hitherto.

An automatic crystal measuring machine has been developed to handle 1200 wafers an hour and to segregate them into different channels so that the subsequent heat treatment can be carried out on conveyor systems at predetermined temperatures according to the wafer thicknesses. On the production lines for audio transistors the wafer thickness varies between $2\frac{1}{2}$ and 4 thousandths of an inch.



Alloying of silicon junction diodes

A special technique has been introduced by the company, using a heated centrifuge to produce effective glass-to-metal sealing. The centrifuge which was developed at Wembley is in the form of a rotating annular boat with a fitted lid, the whole assembly being installed in a firebrick enclosure. The boat is flushed with an inert gas and is heated by a series of gas jets in the enclosure. The components for a large number of glass-to-metal seals are assembled radially in a circular jig which is then placed in the boat. Thereafter the process is automatic, the cycle being started by setting the rotational speed as desired. Then the brick lid is automatically lowered to cover the rotating boat and ignite the burners which heat the boat and its contents to a preset temperature. After this temperature has been maintained for a given period the gas supply is turned off and forced air cooling under controlled conditions is initiated to anneal the seals while they remain in the inert atmosphere. Then the boat and its contents cool to handling temperature.

Another process that was introduced by the G.E.C. is that of cold welding for the final hermetic sealing of the transistor envelopes. The metal surfaces to be joined are first cleaned to prepare them for compression between dies to produce a welded joint. The surface films remaining after cleaning are dispersed by the controlled lateral flow of the mating surfaces and contact under pressure is obtained between perfectly clean metals. Thus a true homogeneous weld is obtained without the application of heat and the electrical and thermal conductivities of the joint are equal to those of the parent metal. The absence of heat, solder, flux vapour, weld flash or gas flames ensures that the transistor cannot be damaged or contaminated during the sealing process; this immunity is a basic condition of long life stability.

Refinements in Steel Specifications for Greater Uniformity

By J. F. SEWELL

THE steady development and increasing efficiency of engineering products would be hampered if it were not for the parallel progress being made in the control of the quality of the raw materials. The tolerance for variations in quality becomes less as production methods become more continuous and automatic so that the engineering industries are ceaselessly seeking and demanding greater consistency. Methods of production are, in general, as advanced in the motor industry as in any other engineering undertaking, and as competition is keen, the constant pressure on raw material suppliers is understandable. In the case of steel, the British motor industry sometimes feels that its American counterpart enjoys an advantage through the willingness of their steel industry to supply to apparently narrower ranges of chemical analysis and consequent greater consistency. In this note, which is chiefly concerned with alloy steels, the actual situation is examined and some suggestions made which could help towards giving the British user greater satisfaction.

As a broad generalisation, the Americans start with an immediate advantage arising out of the scale of their operations. All components can be, and usually are, bought in cast quantities in order to reduce variability as far as possible. This is also encouraged by the steelmaker for his own benefit as recognised in the Americans' price structure, where basis quantities are considerably larger than they are in most cases in Britain. The fact that much of the criticism of lack of uniformity of British steels occurs in the cases of small components with their consequent small tonnage production underlines this problem. There is more to it than this, however. Modern mass production heat treatment methods have created a demand for a continuous flow of components which will give a regular response to the rigidly standardised conditions. Such consistency is particularly important in the case of alloy steel gears and in carbon steel parts which are to be induction hardened. Through the form of their specifications American engineers can rely upon more uniformity in the chemical analysis of their steel, compared with British engineers ordering to British standard specifications.

In America, the Society of Automotive Engineers promoted its own specifications in conjunction with the American Iron and Steel Institute. These specifications require only chemical analysis and usually to narrower limits than those applying in Britain. More important, however, is the fact that each specification falls into a series of steels of abutting or overlapping chemical ranges as is illustrated by the following carbon steels :

	Carbon percentage	Manganese percentage
SAE.1017	0·15/0·20 ...	0·30/0·60
SAE.1020	0·18/0·23 ...	0·30/0·60
SAE.1023	0·20/0·25 ...	0·30/0·60

Thus outlets are provided for casts which fail to meet the actual range specified and, at the same time, cast selection to comparatively narrow ranges of chemical analysis is possible. The value of this arrangement can be assessed from the fact that in a statistical survey carried out by the American Iron and Steel Institute, it was shown that in open hearth alloy steels, the American steelmaker on average fails to meet the desired limits in $15\frac{1}{2}$ per cent of his casts.

The American automobile industry being far and away the largest buyer of steels for heat treatment, has, through its own specifications and through its co-operation with the American Iron and Steel Institute, been able to exert considerable influence on the steel specifications in general use. The British specifications, on the other hand, were drawn up for a more general engineering market than the motor industry. Although British standard specifications allow wider analysis limits than Society of Automotive Engineers specifications, they stipulate a range of mechanical properties which have to be met within limits placed upon the heat treatment, which has the effect of restricting substantially the analysis range available to the steelmaker. Again, in some of the British specifications analysis sub-divisions, comparable to the limits of SAE specifications, are provided within the overall range and when these are ordered the steelmaker is relieved of the responsibility for the mechanical properties of the steel.

It may have appeared to British users who have run into difficulty over steel supplies through trying to improve their position by ordering their components to an SAE specification, that there was some lack of co-operation on the part of the steelmaker. This is far from the case and the answer is simply one of hard fact. It is

fundamental to American practice that there are adjacent specifications in each series to provide an outlet for the occasional cast which inevitably finishes outside the narrow analysis range. By means of this series arrangement the American steelmaker is able to get reasonable assurance, either from customers in general or, if not, from the individual customer, of orders covering an adequate spread of specifications. Orders for steel to a single SAE specification are equally unsatisfactory to the British steelmaker and order cover for adjacent specifications is just as necessary.

In order to enjoy the benefits of steel supplies to narrow ranges of chemical analysis, therefore, it is necessary for the user to engineer his designs in such a way that he can order two, or preferably three, adjacent specifications in each type of SAE steel he wishes to use. There is a steady trend in this direction in this country, like the growing use throughout the motor industry of various steels in the SAE.8600 series. In these circumstances, there is no reason to believe that the British steelmaker is in any way failing to match the American steelmaker's performance. The chemical analysis sub-divisions of some of the British En specifications, mentioned earlier, have been sufficient to satisfy some users' requirements even though these are not carried to the point of refinement reached in the SAE specifications. Furthermore, there are one or two users in this country who have developed their own series of specifications recognising the principles which have been outlined.

In conclusion, it would seem that the so-called advantages enjoyed by American steel users over their British counterparts may reflect a higher degree of sophistication in their approach to engineering design and its related steelmaking problems. A movement in the same direction already exists in this country, one result of which is that there is a progressive departure from the En series of British standard specifications, and the time is perhaps not far distant when collaboration between engineer and steelmaker will lead to the development of a new range of British standard specifications for alloy steels incorporating the concept of several series of related specifications. What is beyond question is a growing disinclination to use En alloy steels and, indeed, many of the specifications now listed have gone out of use.

Weighing the Risk

THE EMPLOYER'S DUTY TO ENFORCE SAFETY MEASURES

By a BARRISTER-AT-LAW

WHEN a young mother relates, towards the close of the day, some particularly distressing piece of behaviour from the infant of the household, the first question which springs to the mind of any self-respecting husband is " And what were you doing at the time ? " This is not because the master of the house fails to recognise the blemishes in the character of his child, and attributes all the blame to its mother, but merely because he knows that the average infant needs supervision as well as a set of rules. If the supervision fails, only for a moment or two, the supervisor must bear a part of the blame for the accident, and since the child cannot be made to accept responsibility for his 90 per cent of the fault . . .

The reasoning of the courts is somewhat similar in the case of industrial accident. Most of the injuries which occur to workmen can be attributed in large part to carelessness of their own, but if there has also been some failure of the employer to comply with one or other of the many legal duties of supervision which are imposed upon him, and this neglect has contributed to the accident, then the employer must pay his share. The employer who is 10 per cent to blame for an accident is thus liable to an action for damages in just the same way as the most grossly negligent ; and the supervisor who often sees one of his men put his fingers under the guard of a guillotine, or tilt back his mask in the foundry, and fails to break the habit, brings upon the employer a proportionate share of the blame for any later accident or illness which results from the unsafe practice. Child, schoolboy, or grown man, a set of rules without supervision is not enough.

All this is fair enough, but the worry of it for many employers and safety officers is that workmen, unlike schoolboys, are not always amenable to discipline, and when a man is instructed to take safety precautions for his own good and fails to do so, there are limits to what the employer can enforce. Should he sack a man who refuses to keep his thumbs clear of the buzzing cogs or a grinding wheel ? Should he replace with a less skilled worker an experienced maintenance man who persists in ignoring safety precautions 30ft above the factory floor ?

The answer to some of these questions gradually emerges from litigation in the courts. It is usually the serious situations which are dealt with there, but the common problem of the slight offence, when there was little or no risk of serious injury, was dealt with in the Court of Appeal and the House of Lords in one recent case.*

Risk of Slight Injury

A foundry worker who was engaged in handling molten metal slipped and spilt some of the molten metal which he was carrying in a ladle over his foot and ankle. He was injured, although not very seriously, and sued his employers for breach of their duty to provide a safe system of work. The injury would not have occurred if the man had been wearing protective spats, but it is not now, as it once used to be, a bar to the claim of a workman that he is equally at fault himself. He is still entitled to reproach the employer with not having ensured the observance of the safety measures which the man himself has deliberately ignored.

These employers had made safety spats available to their workmen, and they also supplied protective boots at cost price. They had not, however, obliged this particular workman to wear the spats, or even advised him to do so, because he was an experienced workman. The County Court judge who first tried the matter felt that this was not a sufficient discharge by the employer of his duty to take all reasonable steps for the safety of his workmen. He felt that the least that should have been done was to attempt to educate all employees in the use of protective clothing, even when, as with this man, the risk of accident was small and any resulting injury would have been slight. He therefore held the employers partly liable for the accident to the extent of 25 per cent. Although the workman's carelessness had thus contributed 75 per cent of the cause of the accident, the man won the claim and with it the right to costs. The total damages assessed by the judge were £233, so that the costs were almost as important a factor in this case as the award.

Both the employers and the man appealed to the Court of Appeal, and the employers finally to the House of Lords. The Court of Appeal had sympathy with the employers, but left the judgment untouched ; the House of Lords held them not liable. Had the workman been inexperienced, there is little doubt that his claim would have succeeded, for all the Judges recognised that the employers were under a duty to warn and educate the less experienced among their men, even though the risk of accident was low and the possible injury not serious. As the man was experienced, however, the House of Lords felt that it was quite sufficient in these circumstances merely to make the protective clothing available.

Strangely enough, although the Judges rather stressed the point that the employer's duty was low for minor dangers, the duty is not very different from the duty to enforce other safety measures even when it is a matter of life and death. Unless there is a specific direction in the Factories Act, or in statutory regulations, the duty of the employer is to take all reasonable steps for the safety of his employees, and no higher. Some men, for instance, prefer to work at a height unencumbered by a safety belt, though a fall may well mean fatal injury, because they are a little conservative in their ways, and the safety belt itself has its own dangers : the ties and attachments may well cause accidents. Although it may be obvious to all that the wearing of a safety belt may be a matter of life and death, however, there does not seem to be an absolute duty cast upon the employer to ensure that it shall be worn. If the workman refuses, or intentionally neglects constantly to comply with the directions of the employer in such circumstances that it is a choice for the employer of either acquiescence or dismissal, the employer is not in breach of his legal duties if he accepts the position and confines his efforts to exhortation and education.

Workman with a Weakness

Somewhat similar is the problem of the employer when any given situation may give rise to an accident of particularly serious consequences for the reason that the workman himself is peculiarly vulnerable to injury. The courts were exercised to some extent to decide, in a case some years ago,† whether there was any higher duty on the employer of a one-eyed man to ensure his use of goggles than there was in the case of the average man with two eyes. A garage hand was removing the U-bolt from the back axle of a vehicle when he had an accident with very serious results. The bolt had rusted in, and he struck it with a hammer. A metal chip flew out and injured him in his only good eye. He claimed against his employers, alleging that they should have ensured the use of goggles for this work. The job was admittedly not one for which goggles were usual for normal persons with two eyes, and the question of principle exercised the lawyers up to the House of Lords. Eventually, the decision went, by a majority, in favour of the

* Haynes *v.* Qualcast (Wolverhampton), Ltd. 1958 1 W.L.R. 225. Qualcast (Wolverhampton), Ltd., and Haynes 1959 2 W.L.R. 510.

† Paris *v.* Stepney Borough Council. 1951 A.C. 367.

man, and the employers were held responsible for a breach of duty.

The inference from this case is that the employer is probably under a stricter duty to those of his employees who are more susceptible to injury, or more likely to suffer severely from accidents, for one of several possible reasons. A one-eyed man would suffer more from an accident to his good eye ; a deaf man would suffer more from the loss of his sight than would a man with normal hearing and would, as well, be more likely to sustain an accident because he would not be able to hear danger approaching or hear a warning shout from anyone near ; and a man with a thin skull would be more likely to sustain serious injuries from a slight accident. All these men appear to be entitled to expect more care from their employers and from the supervisory staff.

The Normal Workman

Of wider application, however, is the question of the standard of care which the employer owes to his normal workman—the man in possession of his senses and unlikely to sustain more than normal injury from an accident. Perhaps the first observation to make is that the expression " in possession of his senses " is not meant to imply that if the workman does something silly the employer is absolved from blame for any resulting accident. Employers have been held partly to blame when workmen have climbed up several feet off the ground, quite against factory instructions, to clean moving machinery, or replace bands ; when guards on obviously dangerous moving parts have been removed for speed of working or to make adjustments which ought to have been left to maintenance men ; and when young workers have handled and dropped objects which others, with a moment's reflection or a grain of commonsense, would have lifted the proper way or would have handled only with assistance. It is the duty of the employer to take into account all the follies of his workmen which he may reasonably expect from his experience as an employer, or by the use of a little imagination.

Varying Standards of Care

The duties of the employer must begin, of course, with the Factories Act and the many statutory rules and regulations which supplement it. Neither the Factories Act nor these other regulations, however, merely lay down a series of rules which every employer must follow. Obviously what is essential in one set of circumstances is superfluous in other places, at other machines, or for other operations. There are certain operations, first, and certain machines, which are themselves so dangerous that an absolute duty is laid upon the employer to observe certain minimum precautions at all times. Such are the regulations requiring transmission machinery and moving parts to be fenced. (Sections 13 and 14.) Whether any particular piece of machinery is safe or dangerous, the employer ignores the requirement at his peril, and runs the risk not only that his employee will recover damages if an accident happens, but also that he will be prosecuted if a passing Inspector should visit his factory.

Just as certain parts or types of machinery require minimum precautions, so some specific operations require certain minimum safety precautions. Section 12(1), for instance, of the Blasting (Castings and Other Articles) Regulations, 1949, is clear and permits no excuses : " There shall be provided and maintained for the use of all persons employed in a blasting chamber . . protective helmets . . and every person shall wear the helmet . . whilst in the chamber . . ." If, under any circumstances, it comes to the notice of the employer that his men are failing to comply with the regulation, he is responsible for the breach, and must enforce the observance even to the point of dismissing those who may feel like refusing.

Other regulations approach the position in a different way : the Vitreous Enamelling of Metal or Glass Regulations state that it is the duty of the employer to provide and maintain head coverings and overalls, and (Section 14) that it is the duty of every employed persons to wear the overalls and head coverings provided. Here, even though the employer is not primarily liable if there is a breach, he would obviously bear some responsibility if he did not take all possible steps to ensure that his employees complied with the duty laid upon them. It is, of course, the duty of the employer to bring such a statutory duty to their notice in the first place.

At first sight other regulations appear not to be so strictly enforceable upon the employer. The question of goggles leads to a consideration of a somewhat strange mixture of duties, according to the degree of danger to the eyes. For dry grinding of metals, welding and fettling, for instance, the Protection of Eye Regulations of 1938 require only that goggles shall be provided. Perhaps it is safe to assume that the men will wear them for such an obvious danger as may arise to the eyes from such operations. Nevertheless there are cases in which the employer must not only provide goggles, but should also actually ensure that they are worn. The Iron and Steel Foundries Regulations, for instance, provide that every employed person shall use the equipment provided, and the employer will permit a breach of this at his peril.

A Wider Duty

It is not only under the Factories Act and statutory regulations that duties are imposed upon the employer. Whenever any danger becomes apparent from a type of work it is his duty to take immediate and effective steps for the safety of his employees. As soon as it was discovered, for instance, that there was a real danger of silicosis or pneumoconiosis from the minute particle of silica which floated in the air of foundries after all the visible dust had settled, it became incumbent upon all foundry employers to equip their men with effective masks. Similarly, should it be discovered that adhesives or plastics bring their own dangers of dermatitis or skin disorders, the employer will be considered in breach of his primary duties towards his employees if he does not take immediate steps to protect them. The duty commences directly the information comes to the employer's notice or when it is published in normal trade publications or Government reports which ought to be circulated among the supervisory or safety staff.

It might be thought that the employer should bear no part of the blame if the particular danger which causes harm to one of his men was unknown to him and his safety officers. This is not always a valid excuse ; in fact, it fails more often than it succeeds, and is true only in the converse. If a danger was unknown to the employer, and could neither have been discovered by normal trade reading nor expected by the use of normal foresight, then the employer is generally not liable. Once an accident occurs, however, or an illness is traced to some definite cause, it immediately becomes imperative for the employer to take appropriate safety measures. His list of duties, and the occasions on which he is under a duty to provide protective clothing, is thus always liable to expand with each new discovery in the laboratory, and each new accident or illness at the bench.

Sometimes it seems almost a good thing that the employer does not know the financial risks he is running at his factory when his workmen fail to carry out the safety precautions which prudence dictates and which are periodically reaffirmed in black and white. His insurance premium, of course, gives him the average cost of accidents calculated actuarially, but if he were to fill his head with the possible cost of a run of bad luck on his own premises he would be appalled at the risks which are run practically every time one of his workmen hits a cold chisel.

The Test of Foresight

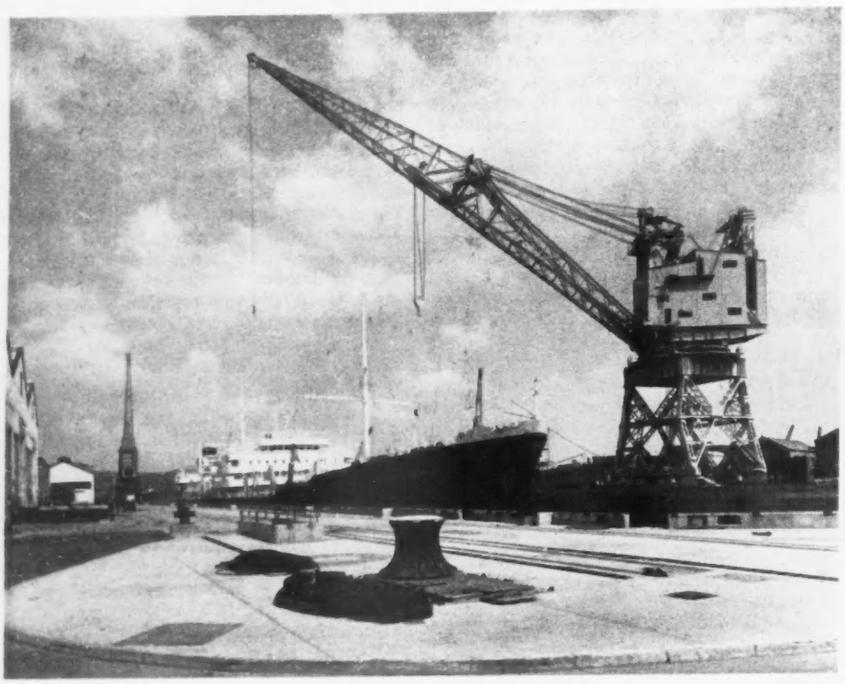
The employer cannot, though, provide against every possible risk, or effectively prevent his men from breaking the rules at odd moments. What he can do, and what he must do, is to observe all the precise rules which are laid down in the Factories Act, whether or not it appears likely that an accident will be caused by any failure to observe them. After that, he has a duty to look around at the actual methods of his men, if they are to a certain extent left to their own devices for achieving the results he wants. Alternatively, he may lay down his own devised procedure, when he keeps closer control over the working methods of his employees. In either case, he has a positive duty to devise a safe method, which will guard against every foreseeable accident. Foreseeable, for this purpose, includes those accidents caused solely by the employee's own carelessness : if the employee is injured by his own fault or neglect, it implicates the employer at once if the injured man can say with truth that his carelessness was known to the supervisory staff.

The employer has to remember, on top of this, that the range of " foreseeability " is gradually extending. If experienced moulders carry ladles of molten metal every day for twenty-five years without an accident, it lessens the blame which is cast upon the employer when the metal is spilt one day, because the employer can say that the grease upon which he slipped, for instance, had no business to be there and could not have been expected. Once, though, the publicity of one accident has shown the possibility of grease in the path of the man with the ladle, the accident becomes foreseeable. Legal principles change slowly, but the application of them in the factory extends every year.

For the most part, though, the prevention of accident and disease at the factory is still a question of education of the workman. If workmen studied the records of industrial insurance companies, or even the accident books at their own works, and used only a very little imagination, they might well take more care for their own safety and for that of their colleagues. Until that day arrives, the employer must continue his efforts for their enlightenment, and work constantly to reduce his own risks.

Shipbuilding Statistics.—The Shipbuilding Conference announces that in the third quarter of the year forty-seven ships of 48,000 tons gross were ordered, bringing the total of new orders placed this year to 129 ships of 146,000 tons gross. At the end of September the order book of the industry stood at 514 ships of 4,473,000 tons gross, valued at £660 million, compared with 670 ships of 5,953,000 tons gross at the corresponding date in 1958.

Large Dry Dock Crane



A jib crane with a capacity of 48 tons at 105ft radius, which has been installed at the new Queen Elizabeth dry dock of Silley Cox and Co., Ltd., at Falmouth, can be seen in the photograph we reproduce on the left. This crane of level luffing design has been constructed to the particular requirements of the dock which is capable of handling tankers of up to 85,000 tons deadweight. It was designed and built by Stothert and Pitt, Ltd., of Bath, and we are indebted to the chief engineer of the company, Mr. T. E. R. Torrance, M.A., A.M.I.Mech.E., for the details given in the following description.

A CRANE for dry dock service must satisfy a number of specialised requirements and is normally designed to suit the particular dock concerned. With the advent of the super tanker and the development of corresponding dry dock facilities, there is an increased need for cranes of large capacity and outreach whose design and construction involve a number of interrelated mechanical, structural and electrical problems. Such a crane, designed and built by Stothert and Pitt, Ltd., Bath, was recently put into service at the new Queen Elizabeth Dock at Falmouth. This crane, which can be seen in our illustration, weighs 636 tons unloaded, and at minimum radius its jib nose is some 247ft above quay level. The dock accommodates tankers up to 85,000 tons deadweight and the crane duties were specified in consideration of probable lifts to be handled in the overhaul of such vessels. To meet the requirements the main hook capacity of the crane was settled at 48 tons with a maximum working radius of 105ft which takes it 11ft beyond the centre line of the dock. There was also required on the crane an auxiliary hoist having 15 tons capacity up to 156ft maximum radius and 12 tons capacity out to 175ft radius to enable loads to be handled at the remote side of the dock. Finally, provision was required for the occasional lifting of 61 tons on the main hook.

For very large luffing jib cranes there is a practical limit at which the use of wire rope purchases to hold the jib gives place to the screw and nut system. In the case of this crane the use of the less expensive rope system was made possible by achieving an accurate level luffing characteristic and by reducing jib weight as far as practicable. The weight of the jib itself is closely balanced by a sliding counterweight suspended at the rear of the crane. As both the main and the auxiliary hooks are made to follow a horizontal path when the jib is luffed, the luffing drive has only to overcome friction, inertia and wind resistance, and can be of comparatively low power. Different means are used to achieve the level hook path on the main and auxiliary hoists. On the auxiliary hoist there is a modified six-part "Toplis" reeving which produces the desired effect by the positioning of the pulleys and multiple rope reeving. The main hook is suspended by four parts of rope necessitating a more complex system in which the anchor part of the purchase is wound on a section of the luffing barrel. Here again pulley positions play a part in ensuring accuracy of level hook path. The makers state that the measured deviations on test were $\pm 2\frac{1}{2}$in for the main hook in 60ft range and ± 5in for the auxiliary hook in 107ft range.

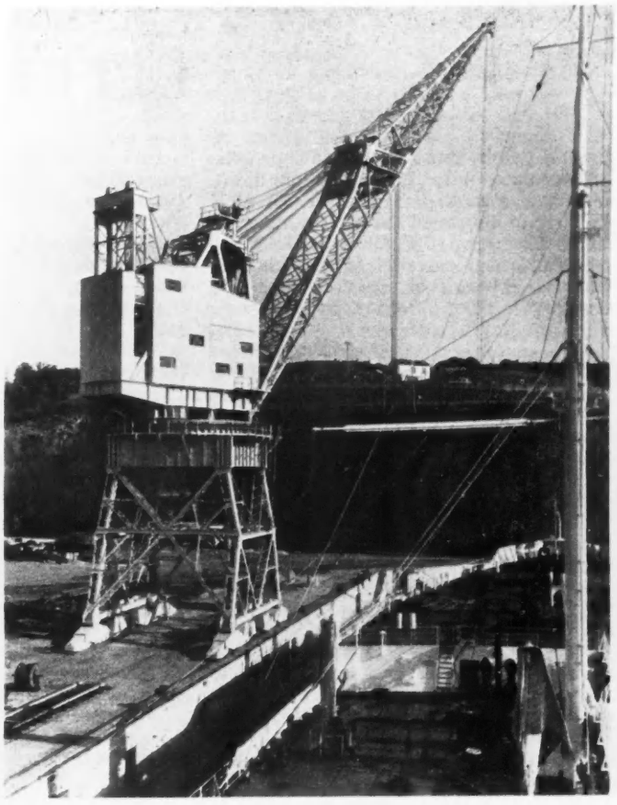
The crane jib weighs 55 tons, and is of riveted lattice braced construction having main chords and bracings in high tensile steel to B.S.S. 548. It is 195ft long overall and can be derricked from a position with the nose at ground level by a modified reeving of the rope system, an arrangement which facilitates erection and maintenance painting. For the twin part reevings which support the jib from the superstructure apex, there are used $1\frac{1}{2}$in diameter steel wire ropes of 6/25 construction. Two parts are wound on a 5ft diameter cast iron barrel which also winds the ropes supporting the jib counterbalance at the rear of the superstructure and the main hoist compensating part referred to above. Although this luffing barrel weighs 8 tons, it requires only about 25 h.p. to luff a 48-ton load at an average speed of 40ft per minute, by reason of the accurate balancing and level luffing characteristics of the crane. The slip-ring motor used for this motion is contactor controlled and rated at 45 h.p. to provide for adverse wind conditions.

The crane superstructure is supported on a live ring of conical rollers with a centre pin for location. The slewing motion is driven from a 35 h.p. slip-ring motor giving a speed of 0·4 revolution per minute or 440ft per minute at the maximum radius of the auxiliary hook. In this motion a worm and spur gearing transmits the drive to a steel slew pinion engaging a rack of 160 pins made integral with the circular girder on which the superstructure revolves.

Welding has been used extensively in the construction of the crane: in the plate girder construction of the truck top, circular girder, segmental girders and machinery bed, the single web form has been adopted in preference to the double web owing to the possible danger of unchecked and unobserved corrosion occurring inside the latter. The design and size of some of the major welded components is shown in one of our illustrations. The legs of the gantry are also of welded construction, but for making the field joints and assembling the main lattice braced parts of the crane structure riveting has been used. The total weight of structural steelwork is about 315 tons and every component was grit blasted at site before priming painting, a precaution which was considered worth while in view of the corrosive marine atmosphere and the very high cost involved in repainting such a large structure.

Ship repair work demands extreme flexibility in the hoisting control because many lifts are made from lower decks of the vessel through restricted access trunkings. With the load out of the driver's view and obstructions to be avoided at various levels, it is necessary to provide smooth speed variation down to low stable creep speeds which can be maintained for long periods. For these reasons the use of Ward Leonard control was an obvious choice, and both the main and auxiliary hoists are driven by d.c. motors from a single 42kW motor generator set which can be switched to either machine as required. The main hoist has a rated speed of $7\frac{1}{2}$ft per minute for 48 tons load and a mechanical change of gear ratio is provided to give 15ft per minute for 24 tons load. The hoist motion driving motor

Crane with jib during assembly and lowered to quay level



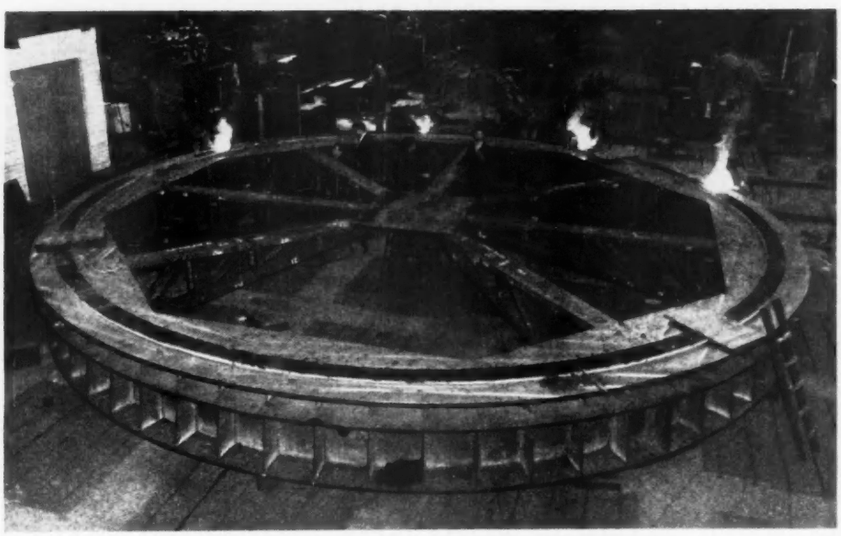
Crane serving a ship in dry dock

develops 50 h.p. at 720 r.p.m. and is a compound wound machine with a separate motor-driven cooling fan to provide for long runs at low revolutions. The auxiliary hoist has a motor of similar design, but of 40 h.p., giving a rated hoisting speed of 30ft per minute with 15 tons load.

In a dock which is frequently called upon to serve unfamiliar ships, it is helpful to have some means of knowing the weights of components lifted and for this purpose both main and auxiliary hoists have been equipped with electronic weighers. For these weighers rope deflector sheaves in the crane superstructure are linked with load cells, the readings being shown on dials in the driver's cabin. An accuracy of $\pm 1\frac{1}{2}$ per cent was obtained with this equipment on test.

To comply with the requirement for an occasional lifting duty of 61 tons with the crane the main hoisting motor and machinery are designed for this greater capacity. In the case of the structure, use was made of the duty classification in British Standard 2452 which covers high pedestal jib cranes. The structure is designed to the Class II or "Normal service" permissible stresses for 48 tons load, but the Class I or "Occasional service" stresses are not exceeded with the 61 tons load.

As time is important in ship repairing and heavy lifts may have to be travelled the length of the dock, the design of the crane travelling motion received special attention. With the crane handling a 48-ton load in 5 lb per square foot wind the most heavily loaded bogie assembly carries a load of 255 tons. The six centre flanged wheels which share the load at each corner run on double 90 lb per yard flat bottom rails. Three of the bogie wheels at each corner of the crane are driven to obtain favourable distribution of tractive effort under varied loadings. The driving motors are mounted on the bogie structures complete with their worm and spur reduction gear units, the four motors being contactor controlled on the Igranic "Torquil" system and totalling 140 h.p.



Large welded component during assembly at maker's works

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

ELECTRO-PLATED COATINGS OF NICKEL AND CHROMIUM

No. 1224 : 1959. Price 5s. This standard is a revision of an earlier specification. The standard has been revised, at the request of industry, as a step towards improvement in quality of chromium plating and an answer to the all too numerous complaints about the lack of durability of many plated surfaces. The most important change in the new edition of B.S.1224 is a provision for thicker coatings of nickel. Until recently nickel has been in short supply, but with the end of this shortage there is no longer any reason why a more adequate nickel coating should not be applied. A second important change in the British Standard is the inclusion of more stringent laboratory tests which plated products must be able to pass if compliance with the standard is claimed for them.

In all, nine tests are prescribed in the standard. They include tests for corrosion resistance, tests to check the thickness of both the nickel and chromium surfaces deposited on an article, and tests to ensure that the plated finish will not easily peel away.

In gauging the thickness of the layer of nickel which is called for in the standard the use of a non-destructive instrument developed by scientists at the British Non-Ferrous Metals Research Association is permitted. Hitherto this assessment could only be made by testing a sample to destruction.

Three grades of plating are called for, depending on the use to which the plated products are to be put.

LITERATURE

Uplift in Gravity Dams. By SERGE LELIAVSKY. Constable and Co., Ltd., 10, Orange Street, London, W.C.2. Price 45s.

IN a recent discussion* at the Institution of Civil Engineers, Sir Richard Southwell recalled that it was the famous Drapers' Company Memoir of Atcherley and Karl Pearson *On Some Disregarded Points in the Stability of Masonry Dams*, " which first made him realise the existence of a thing called research—that the theorems taught to him had not been delivered, once for all, on tables of stone." Perhaps the strongest reason for commending Dr. Leliavsky's book on *Uplift in Gravity Dams* is its suitability for bringing the same realisation to a younger generation of civil engineers.

Dr. Leliavsky is well known for his contributions on the subject of uplift in gravity dams. He has for many years been a strong supporter of the view that the uplift force to be taken account of in design is not merely due to the presence of water under pressure in fissures in the rock foundation and in cracks in the concrete, but is due rather to the action of water under pressure throughout the entire pore space of both intact rock and uncracked concrete. This view has been the subject of much controversy in the past and in some quarters is still not accepted.

In the book under review Dr. Leliavsky gives an interesting outline of the development of views on uplift from the time of the sensational failure of the Bouzey dam in France in 1895 up to the present day. His treatment of uplift is divided into four parts : earlier theories, new theories, experimental approach and relevant problems ; and structural methods for reducing uplift pressure and leakage in dams.

Two main themes run throughout the book : first, the mode of action of water pressure in the pore space of concrete, in particular when associated stress conditions lead to rupture ; and, secondly, the impact of uplift criteria on the design of gravity dams.

The first theme is illustrated by the parts played, in particular, by Fillunger, by Terzaghi and by Leliavsky himself in developing the theoretical and experimental basis of the modern view of uplift. These sections, together with the detailed presentation of Leliavsky's own experimental work, form the most interesting parts of the book. Dr. Leliavsky describes the unfortunate controversy which arose between Terzaghi and Fillunger about uplift. His own references to the more recent work of McHenry and of Serafim show that the controversial nature of the subject persists. It is possible to query, for example, whether, *in terms of the state of stress in the zone of rupture*, there is anything to be learned from Dr. Leliavsky's type of test which could not have been learned from Fillunger's. In principle, both tests give the combinations of total stress (or total force per unit area) and pore pressure which lead to failure by extension, though it may perhaps be held that it is easier to relate Dr. Leliavsky's test intuitively to the state of stress near the upstream face of a dam. If the area over which uplift acts can be deduced from the one it can surely be deduced with equal validity from the other ; but in the interpretation of both tests an assumption about the criterion of failure of concrete in tension is implied, and Dr. Leliavsky's assumption has been questioned.

How the development of ideas on uplift has influenced design rules and methods of construction forms the other main theme of the book. Much of the earlier work in this field was published in German and English-speaking engineers will be grateful to Dr. Leliavsky for his summary of this work.

His treatment of more recent work is rather uneven in emphasis. Flow nets in concrete dams are described in considerable detail, and work on buttress and even arch dams is included (incidentally an illustration of an arch dam seems hardly appropriate for the dust cover of a book on gravity dams). However, contributions by Brahtz and, more recently, by E. H. Brown on the inclusion of the resulting pore pressures in the stress analysis or design method used are not discussed. The reader may get the impression that an intellectually satisfying synthesis has not yet been achieved between the experimental facts regarding the influence of pore pressure on the deformation and rupture of concrete, on the one hand, and current design rules and methods of stress analysis, on the other.

Selected Methods of Analysis of Foundry Materials : Part 1, Pig Iron and Cast Iron. By THE BRITISH CAST IRON RESEARCH ASSOCIATION, Bordesley Hall, Alvechurch, Birmingham. Price 12s. 6d. to B.C.I.R.A. members ; 17s. 6d. to non-members.

IN 1950, the British Cast Iron Research Association set up its Methods of Analysis sub-committee, which was able to gather information, not only from its own well-established chemical laboratory, but also from experts working elsewhere. The members of the B.C.I.R.A. have laboratories covering a wide variety of fields, in routine analysis, research and education, but all of them have a common interest in cast iron. This work of co-operating in testing out analytical methods is continuing.

It may help, therefore, to recall that another of the D.S.I.R. research associations, the British Iron and Steel Research Association, did much good work in testing out the various methods of analysing steels. That work greatly aided the committee of the British Standards Institution which, at a later date, made available the valuable series of British Standard methods for the analysis of steels. So now the work of the B.C.I.R.A. will be of help to all makers and users of cast iron ; the present book is headed *Part 1 : Pig Iron and Cast Iron*, and it should be received with pleasure by many laboratories and technical colleges.

The fundamental treatise on the subject of the *Chemical Analysis of Cast Iron and Foundry Materials* was written by Westwood and Mayer, and its publication in 1951 was sponsored by the B.C.I.R.A. It is now out of print, and work has begun on the preparation of a new edition. Large volumes are all too easily damaged accidentally when used by a chemical assistant at work on the laboratory bench. It was therefore wisely decided to produce the present volume, as the first of four parts of a manual of selected methods of analysis, in a simple, inexpensive and handy form. Its slim form of only ninety-seven pages, neat plastics binding, 10in by 6½in size, and clear print are just what is wanted in the laboratories.

This Part 1 covers sampling, which is of fundamental importance, and the determination of carbon, silicon, manganese, sulphur, phosphorus, nickel, chromium, molybdenum, copper, titanium and vanadium. Methods for the spectrophotometric determination of manganese, nickel, chromium, copper, molybdenum, titanium and vanadium show how physical methods are replacing chemical methods in the analysis of cast irons. If these methods are later to be made into British Standard methods it is to be hoped that they will be brought into line with B.S. 1121 : " Methods for the Analysis of Iron and Steel," which now has about forty parts available in print. This valuable series was started so that each was built up on a similar framework of headings and each concluded with an indication of the range of accuracy to be expected if the method were used in a normally well-equipped laboratory, by a properly trained assistant.

It is proposed that the remaining three parts of this B.C.I.R.A. Manual will deal with the analysis of alloy cast irons and ferro-alloys : slags, refractories and fuels ; and methods for residual elements. These methods of analysis will be used by laboratory specialists in the day-to-day control of the uniformity and properties of many engineering materials which have become daily necessities for much modern mass production.

Vibration Engineering. By W. KER WILSON. Charles Griffin and Co., Ltd., 42, Drury Lane, London, W.C.2. Price 90s.

A COLLECTION of some of the vibrational problems encountered by such an eminent engineer as Dr. Ker Wilson forms a valuable addition to one's technical library. The title, *Vibration Engineering*, is misleading unless coupled directly to the sub-title, " A Practical Treatise on the Balancing of Engines, Mechanical Vibration and Vibration Isolation." It is not a textbook in the usual sense but is directed to the engineer concerned with vibration problems in prime movers. That it is not a textbook is clear immediately from the list of chapter headings, Chapter I being " Digital Computers."

This extensive work will find most favour with those engaged in detail in the design of reciprocating engines and their installation, and in particular with those young engineering graduates who are starting on such work, having some knowledge of the theory of vibration but little experience in working through a balancing or installation problem. Some prior knowledge of the subject is essential, the claim on the inside of the cover that " the earlier chapters give a thorough exposition of the principles and theory . . . " is perhaps not well-founded. It is assumed, for instance, when calculating the torsional vibrations of a geared system that the equivalent inertias and shaft stiffnesses are already known ; anyone who can determine them can no doubt also work out the relatively simple three-mass case considered in such detail in the book.

Part I deals with torsional vibration and engine balancing. The frequency equations are derived and the forced vibration amplitudes calculated by the torque summation method. No secret is made of the fact that some of these calculations can be most tedious even for a simple three-mass system and the use of desk calculating machines or computers is emphasised. It is appropriately pointed out, however, in the chapter on computers, that the initial mathematical

* *Proc. Inst. Civ. Eng.* Vol. 5, No. 3, page 245.

analysis must be made—" a digital computer cannot think, nor can it be used to solve problems to which there is no known method of solution." One of the most useful aspects of Part I is to show the influence of vibrational and balancing considerations upon the selection of the firing order of a multi-cylinder engine. That this can be a formidable problem is shown by calculating the effective number of firing orders possible ; for instance, for a twelve-cylinder, two-stroke engine, this would be 19,958,400.

The more valuable and extensive part of the book is Section II—" Fundamentals of Vibration Isolation." The several coupled modes of vibration of elastically mounted engines are derived in detail and different mounting arrangements are described. The design of the actual flexible part of the mounting, either mechanical or rubber springs, is also considered.

The book is a somewhat curious mixture of the very elementary—such as a fairly detailed consideration of the undamped forced vibrations of a single freedom spring mass system more than half way through, and the more advanced—such as the influence of elasticity of the foundation on a flexible mounting. The elaborately worked out example at the end of each part, bringing out practically every aspect dealt with, is especially useful. There are many tables and diagrams. The book is clearly printed and well produced. This, no doubt, accounts for the somewhat high price of 90s., but price should not be allowed to influence the acquisition of a book of such lasting value. There is a bibliography, although rather short, and the index appears to be adequate.

Modern Railways. Their Engineering, Equipment and Operation. By CECIL J. ALLEN, F.R.S.A., M.Inst.T., A.I.Loco.E. Faber and Faber, 24, Russell Square, London, W.C.1. Price 45s.

UNDER the title " Re-discovering Railways," we recently referred to the encouragement now being given to publicising the railway industry by the British Transport Commission, and in doing so suggested that " the importance of stimulating interest as widely as possible in railway technique is evident at a time when arrangements have been made to use the services of certain staff of railways in the U.S.A. and Netherlands to tide over a shortage of signal engineers on British Railways." The problem of finding staff for railway service is a real one and, naturally, the question arises as to how far writings devoted to railway subjects can help. Considering the matter from this viewpoint we went on to remark " railway literature has never been more abundant, but much of it produced in recent years has looked back to a period already fantastically remote from the generation which should be providing an intake of technicians." Now we have before us another book on railways, admittedly different from others lately noticed. How far will this new book, entitled *Modern Railways*, from the pen of a well and favourably known author go towards furthering the enlistment of railway personnel ? To anyone toying with the idea of joining the railway service this book may certainly prove of interest. It is one of the most comprehensive reviews of modern railway equipment and operational methods produced in a single volume. It is certainly an ambitious effort, taken as a whole, well carried out even though here and there one finds some curious and wholly unexpected errors. There are in all no fewer than twenty-four chapters, extending over some 262 pages of text, supported in turn by 247 illustrations from photographs and twenty-two diagrams. The subjects treated include " The Development of Railways," " The Permanent Way," " The Steam Locomotive Classes and Wheel Arrangements," followed by others dealing with detail design, handling and maintenance of steam locomotives and " The Last Days of the Steam Locomotive," " Electric Traction," " Diesel and Gas Turbine Traction," " Coaching Stock Design," " Express Passenger Services and Schedules," " The Evolution of Railway Speed." Other subjects include " Signalling, Railway Stations and their Staffs," while a final chapter is devoted to " Administration."

The foregoing is but a brief outline of the scope of this, in many respects, monumental work. The author's writings have hitherto been largely confined to such subjects as locomotive performance from the point of view of the speeds attained in everyday operation and on special trial runs. The series of articles on such matters, which appeared over a number of years in *The Railway Magazine*, are well known and much appreciated. It is therefore not surprising that the chapters on such matters in this new book stand out as being both valuable as a record and of general interest.

Turning to the chapters devoted to the steam locomotive, the author is unfortunately not so happy. The remarks on valve gear seem to require some revision. For instance, to say that it is difficult with cam operation to provide for the " gradual variation of cut-off " is not in line with the facts and in this connection it may not be out of place to call attention to the tests made with the B.R. Class " 8 " locomotive No. 71000, fully described in THE ENGINEER of August 23 and 30, 1957. Then, again, to say that a cut-off of 15 per cent means that for the remainder of the piston's stroke the steam is doing its work by expansion is not really correct, for the reason that at this rate of admission the valve opens the port to exhaust at, approximately, 60 per cent, at which point true expansion terminates. Concerning self-cleaning smokebox equipment, would it not have been better to follow the official description of this arrangement already published ? Further, it is difficult to follow the author's statement that baffle plates " correctly designed do not interfere with draught." However, here again it would seem advisable to call attention to the locomotive test reports published, which provide a wealth of information on performance, including details of the draught losses between the ashpan and the blast pipe nozzle. Such information indicates, amongst other things, that the losses due to the self-cleaning plates (baffles ?) range from 0·5in to perhaps 2·0in of water, according to the rate of gas flow.

Turning to the Churchward internal steam pipe fitted to Swindon boilers, we suggest that the description given does not agree with the drawings published in THE ENGINEER of Churchward's engines, nor does it agree with H. Holcroft's description given in his book *Great Western Locomotive Practice*. While considering steam locomotive details, it may be advisable to point out that the normal distance between the main frames to suit the standard gauge of 4ft 8½in is about 4ft 1in, varying slightly according to the thickness of the frame plates. The distance given by the author of 3ft 3in possibly applies to the " Bulleid " frame arrangement, confined to " wide firebox " designs such as the B.R. " Pacific " classes, as well as to the " Merchant Navy " and " West Country " " Pacific " types on the old Southern Railway.

On page 120, Chapter 9, some remarks are made on the subject of locomotive testing. Referring more particularly to controlled road tests and to the braking units used, it is stated that these are " equipped with electric generators so arranged that their function is reversed and they act as brakes." This does not seem an adequate description. It would have been better to refer to the excellent description given of these testing units by H. I. Andrews to the I.Mech.E. in 1948. What really happens is that the generators driven by the axles of the vehicle act as generators and the power so produced in opposing the drawbar pull of the locomotive is dissipated by banks of metallic resistors heating columns of air provided by fans.

When continuing remarks made on compound locomotives, page 128, Chapter 10, the statement is made that " the Erie Railroad once went to the length of building a triple expansion locomotive." This is, however, quite incorrect. In the first place, the engines referred to were built by Baldwin. They had six cylinders, all of equal size, consisting of two h.p. cylinders exhausting into four l.p. cylinders. They were of the 2–8–8–8–2 type. Many years later, a triple expansion locomotive was built for the Delaware and Hudson, and F. W. Webb is also understood to have built such an engine at Crewe during the latter years of the last century.

In Chapter 12, " Diesel and Gas Turbine Traction," mention of the small diesel hydraulic 60 h.p. locomotive as being a British diesel shunter is open to question. If the author cares to pursue his inquiries further by referring the matter to the Eastern Region, this locomotive may be found to be one of Continental origin (possibly German), fitted with the Lentz hydraulic transmission. Such a locomotive was certainly on trial on the Great Eastern section of the former L.N.E.R. in 1924. Pages 161 and 162 are particularly interesting, because of the remarks made concerning diesel traction on North American Railways. At present, diesel traction in one form or another is being introduced here and the observations made on this subject are of added interest on this account.

In the course of a particularly interesting chapter on " Coaching Stock Design," a reference is fittingly made to the wide use now made of roller bearing journal boxes, offering, as the author states, many advantages. No doubt there may be instances when this kind of bearing reduces running resistances. To what extent this is accomplished will presumably depend on the design of friction bearing with which the anti-friction type is compared. Considered from this viewpoint, it is possible that the Dahlerus paper, I.Mech.E., 1925, may be found of interest. This describes tests made with coaching stock with and without anti-friction bearings for the journal boxes on the Midland Railway. (See THE ENGINEER, February 13, 1925.)

The chapter on " The Evolution of Railway Speed " contains a reference to the so-called Railway Races of 1895, and a plate, XVII, " Engines in the 1895 Race to Aberdeen," illustrates the McIntosh locomotive No. 721, " Dunalastair," as being representative of the Caledonian locomotives employed, whereas, in fact, these famous McIntosh locomotives were not built at that time ; they appeared the year following—1896. Actually, either Drummond's or Lambie's engines were used between Carlisle and

Aberdeen during this remarkable episode in British railway history.

The chapters given up to electric and also to diesel locomotives seem generally to be fully adequate to their purpose, and from the detailed particulars given it is clear some expert assistance has been at hand. It therefore seems regrettable that, when considering steam locomotives which have been given considerable attention, similar reliable assistance was not always called upon.

The numerous excellent illustrations indicate the wide general knowledge possessed by the author of railways and their rolling equipment and are, moreover, in themselves of no little interest. Here and there some of the descriptive captions require amendment. As a case in point, the Baltimore and Ohio articulated Mallet type locomotive illustrated is a simple expansion engine, not a compound, as described.

The text is accompanied by a large amount of data, giving, for example, the railway gauges of the world. Dimensions of British and American steam locomotives, particulars of electric and diesel-powered locomotives, and other information of various kinds go to complete a book which will no doubt find a place on the bookshelves of most railway enthusiasts.

Traction Engines. By PHILIP WRIGHT. A. and C. Black, Ltd., 4–6, Soho Square, London, W.1. Price 21s.

FOR the numerous engineers and laymen who maintain a lively interest in steam railway locomotives and trains, there are many books. For the growing company of those who are enthusiastic about other steam locomotives—farm traction engines, showmen's locomotives, haulage wagons and road rollers—there are few. They, in particular, will welcome this book by the Rev. Philip Wright. The author is an Essex clergyman who, before entering the Church, was a farmer in his native Suffolk. He grew up during those years in which steam ploughing and threshing engines, though still a power on the land, were soon to be succeeded by internal combustion-engined tractors.

In the main, the book is an interesting record of the author's own experience of steam traction engines and of the comments and opinions of the veterans who had a hand in the building and operation of many of them. During the first eighty years of this journal's life, its pages regularly carried technical descriptions of the traction engines turned out by the firms whose names were household words. We, too, grew up with them and find no little pleasure in having them recalled so realistically in this book! There is, for example, the "Agrimotor" built by Richard Garrett of Leiston, Suffolk. By the natives of that county, this engine was dubbed "Old Coming as It Went" because "both smokebox and chimney were behind and over the rear wheels in direct contrast to the usual layout of a steam traction engine. The drive from the shaft to the back axle was by a roller chain and behind the driver's seat was the fire-door."

Steam power has virtually gone from the land, the highway and from the fairground. Nevertheless, all over the country, there are scores of the traction engines that have served the day in which steam power was prominent. The National Traction Engine Club, of which Philip Wright is the chairman, has a membership which is eager to maintain them in working order for as long as possible. Steam traction engine rallies are now a feature of our national life. Every year, at these rallies, the performance of the participants is watched by thousands of interested spectators. This is a book which will appeal to them and many others; it is liberally illustrated by photographs and some of the author's own pen and ink sketches. The steam traction engine has been superseded but there are many who delight to remember it, for they share the opinion expressed by Paul Jennings and quoted by the author in his introduction: "No diesel has drama nor fire in her belly, no diesel is christened 'Britannia' nor 'Nelly.'"

Korrosion und Oberflächenschutz. No. 8 of the TR Special Series. Verlag Technische Rundschau, Hallwag, Berne, Nordring 4, Switzerland. Price Fr.4.80. THE "Schweizerische Arbeitsgemeinschaft für Galvanotechnik" (SAGT), which was founded in 1955, aims to present to industry an up-to-date picture of the science and art of electro-plating. The papers given at the Group's 1957 meetings and previously published in the "Technische Rundschau" have been collected in the present volume which covers "Non-metallic inorganic protective coatings" (G. Elssner), "Phosphate coatings for improving cold drawing and sliding friction" (H. Keller); "Phosphate coatings as adhesion bases for lacquers" (Y. Bary); "The electro-deposition of alloys" (E. Raub); "Galvanic coatings of tin and tin alloys" (B. Keysselitz); "Corrosion protection of steel by means of metallic coatings" (J. C. Hudson).

Obituary

D. J. O. BRANDT

WE record with regret the death of Mr. David Julius Oscar Brandt which occurred on Monday last, November 23, after a long illness. He was well known throughout the iron and steel industry as an able writer on the technical and general affairs of the industry and as a lecturer on many aspects of steelmaking practice.

Oscar Brandt, who was born on Christmas Day, 1919, was educated at Clifton, and studied metallurgy at the Royal School of Mines, which he left with a B.Sc. degree and the distinction of A.R.S.M. He worked for a time with Murex, Ltd., leaving in 1942 to join the Department of Tank Design of the Ministry of Supply. Brandt was engaged in that department until the end of the war on the development and testing of armour plate. He then went to John Miles and Partners (London), Ltd., consulting metallurgical engineers, with whom he remained until 1948, when he joined the British Iron and Steel Research Association as a senior scientific officer in the steelmaking division. He left B.I.S.R.A. in 1955 to practise independently as a metallurgical consultant, and was concerned mainly with the application of oxygen to steelmaking. At the beginning of 1957 he joined Industrial Newspapers, Ltd., to become metallurgical editor of *The Iron and Coal Trades Review* and editor of *Metal Treatment and Drop Forging*. He was a Fellow of the Institution of Metallurgists and a member of the Iron and Steel Institute and the Institute of Metals. But Oscar Brandt was not only an able metallurgist and technical writer. He delighted in conversation and good-natured argument. The technical press fraternity who frequently enjoyed his company will long remember these and his many other qualities.

Technical Reports

Further Developments in Pulsed-Infusion Firing. N.C.B. Information Bulletin 59/211. National Coal Board, Hobart House, Grosvenor Place, London, S.W.1.—Since the publication of information bulletin No. 45/152 the use of pulsed-infusion firing has greatly increased, being now employed at approximately 140 collieries. It was visualised that the greatest potential advantages and the widest application of the system would be in the blasting of solid coal by means of flanking holes, and this has proved to be so. When pulsed-infusion was introduced—and for some considerable time afterwards—single-shot firing was employed. As experience has been gained and the advantages of pulsed-infusion firing more widely realised, developments have taken place and simultaneous and delay firing of rounds of shots have been successfully adopted in many places. This supplement describes these developments.

The Direction of Chip Flow in Oblique Metal-Cutting. By A. C. Rapier, B.S.(Eng.), A.M.I.Mech.E. and P. T. Wilkinson. MERL Plasticity Report No. 156. Mechanical Engineering Research Laboratory, East Kilbride, Glasgow.—A short experimental investigation has been conducted to check the validity of the chip "flow law" in oblique metal-cutting. Cutting tests were carried out in a shaping machine on a number of materials using tools with varying angles of obliquity. A suitable technique was devised for accurate measurement of the angle of chip flow on the rake face of the tool. Results indicated that although a definite relationship existed between the angle of obliquity and the angle of chip flow, in no case was the "flow law" due to Stabler obeyed, i.e. $\beta = \gamma$. In fact, seven results, five of them original, approximated to two non-linear relationships one of which crossed the "flow law."

Tests on Eccentrically Loaded Riveted Joints. By Professor A. J. Francis and G. L. Belcher. Report SM.249, Aeronautical Research Laboratories, Department of Supply, Commonwealth of Australia.—Tests to failure are described on fifteen riveted joints in which 0·080in 24ST Alclad aluminium alloy plates were connected by a group of twenty-four $\frac{1}{4}$in diameter 17ST rivets. The load was statically applied with initial eccentricities varying from 10in to zero. The strengths obtained were, on the average, 55 per cent in excess of the strengths calculated by the usual procedure for eccentrically loaded splices, but only 3·6 per cent below the strengths predicted by a theory which makes allowance for the development of plasticity in plates and rivets. It is suggested that such joints be designed on the basis of the proposed theory rather than by the conventional procedure.

A Theory of the Separated Flow from the Curved Leading Edge of a Slender Wing. By J. H. B. Smith. Reports and Memoranda No. 3116. H.M. Stationery Office. Price 6s. 6d.—The simple model used by Brown and Michael to represent the flow past a slender delta wing with leading edge separation, is extended to treat wings which have pointed apexes, curved leading edges and straight, unswept trailing edges. The vorticity of the fluid near the leading edge is represented by an isolated vortex of varying strength, which is curved in the non-conical cases considered here. A step-by-step method of calculation is used which starts from an assumed conical flow near the apex and employs the condition of zero total force on the vortex system in one cross-flow plane to obtain the configuration in the next. Numerical values of the co-ordinates and strength of the vortex, the lift coefficient and the centre-of-pressure position are found for three plan-form families at different incidences.

Books Received

Space Technology. Edited by H. S. Seifert. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 180s.

The Petroleum Handbook. 4th Edition. Shell International Petroleum Company, Ltd., 1, Kingsway, London, W.C.2. Price 21s.

Absorption. By K. Thormann. Springer-Verlag, Berlin-Wilmersdorf, Heidelberger Platz 3, Western Germany. Price DM 28.50.

Microwave Data Tables. By A. E. Booth. Iliffe and Sons, Ltd., Dorset House, Stamford Street, London, S.E.1. Price 27s. 6d.

Energy Principles in Applied Statics. By T. M. Charlton. Blackie and Son, Ltd., 17, Stanhope Street, Glasgow, C.4. Price 25s.

Fuels and Lubricants. By M. Popovich and C. Hering. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 68s.

Internal Stresses and Fatigue in Metals. Edited by G. M. Rassweiler and W. L. Grube. D. Van Nostrand Company, Ltd., 358, Kensington High Street, London, W.14. Price 72s.

THE ENGINEER

Technical Contributors Section

NOVEMBER 1959

Recent Developments in Steam Sampling and Purity Measurement

By J. JACKSON*

Accurate steam purity measurement is important in power generation because the impurities present in the steam may be deposited in superheaters and on turbine blades, and thus interfere with the operation of the power plant. Up to the present, the withdrawal of a sample of the steam is necessary before the purity can be measured. It is difficult to obtain a representative sample of wet steam, however, since the moisture is present in the form of a film on the pipe walls, and this must be remixed with the steam before sampling is carried out. The conductivity of the condensed steam sample can then be determined, and this gives a measure of the amounts of salts originally contained in the steam, but the results of such determinations may be difficult to interpret if dissolved gases are present in the sample. For this reason, although degasifying devices are available, the use of methods unaffected by the presence of dissolved gases, such as flame photometry, is tending to become more widespread. Techniques are also being developed which can be applied to the entire steam flow, thus avoiding the difficulties associated with steam sampling.

THE steam produced by a boiler is rarely, if ever, a pure substance. This is true even for steam from high-pressure boilers fitted with steam scrubbers, though the amount of impurity present may then be reduced to as little as 0·5 p.p.m. of contained solids.[1] Such small quantities of impurity are, however, by no means unimportant. An impurity content of 0·5 p.p.m., for example, with a steam generation rate of 1,000,000 lb per hour, could lead to the deposition of about 2 tons of solid per annum in the superheater and turbine, though in practice, of course, not all of this quantity of solid would be so deposited. It is because of the serious consequences to which the formation of these deposits can lead that there is a need for reliable and accurate methods of measuring steam purity.

The principal types of impurity present in steam from boilers are :

(i) In wet steam, the droplets or spray of liquid boiler water containing the boiler water substances : salts, silica and suspended matter.

(ii) In superheated steam, the product of the drying out of the droplets of boiler water ; if there is much caustic soda, this may be molten, or may take the form of a sticky dust.

(iii) Gases such as carbon dioxide, oxygen, hydrogen, ammonia and even sulphur dioxide if sodium sulphite is used as a deoxygenating agent.

(iv) Silica and boiler salts dissolved in the steam at pressures above about 1000 lb per square inch ; at such pressures, steam behaves somewhat as a liquid solvent and is capable of dissolving the substances mentioned directly.

(v) Volatile amines added deliberately to the steam to prevent corrosion in the condensate system.

(vi) Corrosion products.

Nothing seems to have been reported on the sampling of superheated steam containing globules of molten caustic soda or a sticky dust in suspension, and this matter will not be considered here. The main concern of this review, therefore, is with the droplets of liquid boiler water and the salts they contain ; for this reason, the term " steam purity " will be taken here to mean the salt content, rather than the total solids content of the steam. This excludes the silica, which is important from the point of view of deposit formation, but a semi-continuous instrument (the Silikometer) is commercially available for the measurement of silica content. The gases listed above are of importance only in so far as their presence interferes with certain of the methods of measuring the salt content.

A distinction must be made between steam purity, as defined above, and steam quality, or dryness fraction ; this is the proportion of liquid water present in the steam. Of course, it is possible to estimate the steam purity from the dryness fraction, if it is assumed that the droplets of boiler water entrained in the steam contain the boiler salts in solution in the same proportions as those in which they exist in the bulk boiler water. For this reason, methods of measuring the dryness fraction are of interest to this review. The literature on this subject up to 1953 has, however, been reviewed by Marshall,[3] and well-known devices, such as throttling steam calorimeters, are therefore not discussed here.

There has been no comparable review in English in recent years of the subject of steam purity measurement, with the associated problems of steam sampling, though a useful survey (in German) of recent Soviet work in this field has appeared.[4] The subject is one, however, in which considerable developments are taking place, and in which there is considerable dissatisfaction with existing methods. This is shown by papers such as that of Place,[5] and by the fact that the tentative standard on steam sampling prepared by the A.S.T.M. in 1949,[6] still remains tentative, even although revised in 1954, while British Standards on the subject, although in course of preparation, have not yet been issued. A review of the subject at the present time therefore seems desirable. This will not, however, be concerned with the practical details of the technique, which are adequately dealt with by Place[5] and Swift.[6a]

Up to the present, the only practical methods of steam purity measurement have had the requirement that a sample of the steam must be extracted and that the purity measurements are carried out on this sample. Steam sampling is therefore considered first, followed by a review of the methods of purity measurement. Because of the difficulties of accurate steam sampling, as described later, methods of purity measurement are now being developed which can be carried out on the entire steam flow, thus removing the need for sampling, and these are described in a final section. None of these methods seems so far, unfortunately to have reached a sufficient stage of development to justify routine use on boiler plants.

* Imperial Chemical Industries Ltd.

Steam Sampling

The sampling of steam containing entrained boiler water was originally regarded as a problem essentially similar to that of the sampling of a dusty gas, i.e. the steam was believed to contain the water in the form of discrete droplets, uniformly dispersed. The essential requirement for accurate sampling was therefore only that the speed at which the sample was withdrawn from the steam main should be the same as that at which the steam itself was flowing through the main, a condition known as isokinetic sampling; the importance of isokinetic sampling was demonstrated by Morris.[6b] Since the dispersion of droplets was believed to be uniform, a single sampling nozzle, centrally placed in the main, would be sufficient.

The realisation that the droplets might not be uniformly dispersed in the steam lead to certain refinements in this procedure, e.g. the introduction of multi-port nozzles, as in the A.S.T.M. Tentative Standard.[6] In addition, this standard recommends that the sampling point should be located, if possible, in a vertical pipe with downward steam flow. Where this is not possible, the next in order of preference is a vertical pipe with upward steam flow, horizontal pipes being the least desirable for the location of the sampling point.

It has become clear in recent years, however, that a truly representative sample of steam containing entrained liquid water cannot be obtained in the manner just described, even with the multi-port nozzle now recommended by the A.S.T.M.[6b] The reason for this is that, in practice, even in vertical pipes and still more markedly in horizontal pipes, the water droplets tend to move as a film along the inside of the pipe walls so that the steam and water do not form a homogeneous mixture. This film of water must not be thought of as possessing a sharp boundary. Its nature has been considered in most detail by Cross,[7] who suggests that it is formed by condensation resulting from heat losses from the pipe as well as by deposition of entrained droplets. With the usual high steam velocities used in practice, the film must be quite thin and there must be a continuous process of deposition and re-entrainment, producing what Cross describes as a rolling action. The existence of such a film has also been reported by Zuharev[8] and Mostofin[9] in the Soviet Union, and by Küchen[10] in Germany.

difficult, it not quite impossible, to locate a sampling port so as to include the film of water in its proper proportion in the sample. The magnitude of the effect, and hence that of the inaccuracies introduced by failure to sample correctly, can be reduced by sampling, as recommended by the A.S.T.M., in a vertical pipe with upward steam flow, but it cannot be eliminated entirely in this way, and it will often not be possible in practice to locate the sampling point in such a position. The fact that sampling wet steam with the orthodox type of nozzle must be inaccurate is, of course, of great importance, since a measurement of the purity of the sample obtained in this way, however accurate in itself, can have little meaning.

Methods for the measurement of steam purity which do not call for the extraction of a steam sample are described later, but up to the present time sampling remains an essential first stage in carrying out this measurement. It is important, therefore, to consider the techniques which have been suggested for improving the accuracy of steam sampling. Because of the difficulty, if not impossibility, of taking a representative sample of a steam/water mixture in which the water is flowing as a film along the inside of the pipe, the accuracy of sampling can be improved only if some means can be found of redistributing the water film over the cross section of the pipe so as to form a homogeneous mixture. Thus Cross[7] has proposed the use of a redistributing device consisting of a modified nozzle set in the pipe, designed to re-entrain the water film from the wall of the steam main, and fitted with a sampling tube located at the expanding portion of the stream after the nozzle. Unfortunately, no further information, either on the design or performance of this "modified nozzle," has been published.

Redistributing devices have also been developed in the Soviet Union. In principle, these devices operate essentially in the same way as that described by Cross; a constriction of some kind is introduced into the pipe, the aim being to increase the steam velocity until it exceeds a certain critical value, above which the film of liquid on the pipe wall is torn off and remixed with the steam. This is achieved, in the device described by Mostofin[9] (Fig. 1) by the use of a mixing chamber formed by a truncated cone, along the length of which are placed a number of conical rings. No information on the design or performance of this device was given by Mostofin in his paper.

A second redistributing device developed in the Soviet Union is that described by Alenchikov *et al.*[12] (Fig. 2) in which a venturi type mixing chamber, rather like that suggested by Cross, is used. The design of this device is based on a formula for the critical steam velocity which, it is said,[12] is due to Professor L. K. Ramzin:

$$w_{cr} = 7{\cdot}5\sqrt{\frac{\sigma}{\gamma}}$$

where

w_{cr} = critical velocity (m/sec.)
σ = surface tension (dyne/cm.)
γ = specific weight of dry saturated steam (kilogramme per cubic metre).

The surface tension is given by the following expression:—

$$\sigma = 0{\cdot}007 \times 10^{-8}(\lambda' - \lambda'')^4$$

The significance of λ in this expression was not given in the paper by Alenchikov *et al.*, but according to a private communication from Professor V. Yu. Lomonosov, λ' and λ'' are the densities (specific weights) of water, and steam at saturation pressure, respectively, expressed in kilogrammes per cubic metre.

More recently, Mozharov[12a] has stated that the Ramzin formula gives values of the critical velocity which are two to three times greater than those found necessary in practice for stripping off the film of liquid from the pipe wall. According to Mozharov, an empirical formula which gives values in good agreement with practice can be written as follows:

$$w_{cr} = 115\sqrt{\frac{\sigma}{\gamma}\left[\frac{x}{d(1-x)}\right]^{\frac{1}{4}}}$$

where x is the moisture content of the steam and d the pipe diameter. Mozharov also points out that, even at very high steam velocities greatly exceeding the critical, a very small amount of the moisture still remains adhering to the pipe wall.

According to Alenchikov *et al.*, the venturi type mixing chamber is superior to that of Mostofin in that it is both more accurate and calls for the use of a smaller steam sample. There is, of course, no experience with either device outside the Soviet Union, and it would not be possible to decide between them on the basis of the evidence at present available. The use of a sharp-edged orifice for redistributing the water film has also been suggested,[11] and some experiments with this device have been reported by Belin and Knox.[11a]

Purity Measurement

After the sample of steam has been obtained, the most widely accepted method, up to the present, of measuring its purity has been to condense it, and then to measure its electrical conductivity, suitable precautions being taken to eliminate interfering substances. Because of the difficulties, described later, associated with the conductivity method, the use of methods based on flame photometry and on radioactive tracers have been suggested recently. The most fundamental method of measuring steam purity, and the one with which all other methods must be compared, is to evaporate the

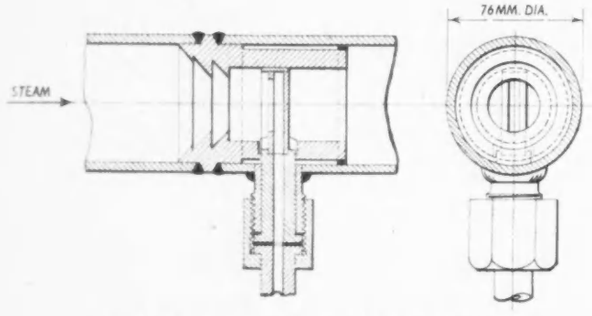


Fig. 1—Steam sampling device of Mostofin (Ref. 9)

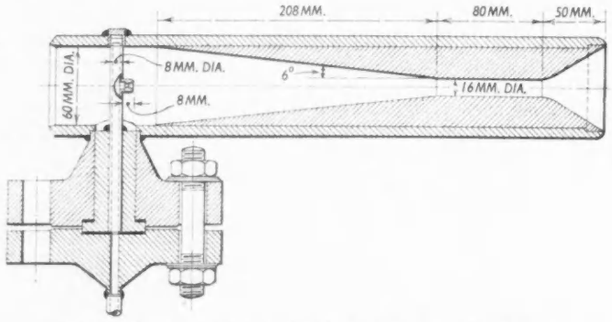


Fig. 2—Steam sampling device of Alenchikov *et al* (Ref. 12)

The same phenomenon has also been recently reported from New Zealand by Banwell[11] and Belin and Knox,[11a] and it has been confirmed by unpublished work carried out by the British Coal Utilisation Research Association. Film formation takes place, not only with fairly wet steam, but also with nearly dry steam from which most of the moisture has been removed by means of cyclones.[11]

As pointed out by Cross,[7] it would be

condensed sample to dryness, and then to weigh the residue obtained, though this gives, of course, the total solid content rather than the salt content. The difficulty with this gravimetric method is that it is slow, and not adapted for continuous routine control. In addition, a large sample of condensate must be evaporated, and since the quantity of the residue is extremely small, the evaporation must be carried out in a dust-free atmosphere. The laboriousness of the procedure can be reduced somewhat by the use of apparatus, e.g. that devised by Rayner and Logie,[13] which is fully automatic in operation, and which shuts itself down in the event of an electrical breakdown or when evaporation is completed. With this equipment, about twenty-five hours are required for the evaporation of a 5-litre sample, and this would hardly be sufficient, since samples of up to 10 litres have been evaporated to give residues of weight less than 0·1 mg.

Conductivity Measurement. — Measurements of electrical conductivity can be of very high accuracy. They must, however, be related, somewhat empirically, to the salt content of the condensed steam sample. Any uncertainties in this relation may not be of great importance in the operation of an established boiler plant, since it is usual to operate at a level of conductivity which is known to be satisfactory. With new boilers, on the other hand, some initial experimentation would be needed in order to determine what level of conductivity was, in fact, satisfactory. It would then only be necessary to observe any deviations from this level, independently of its true significance in terms of salt content.

The need to remove interfering substances has been mentioned already. These substances, in the case of measurements on condensed steam, are the gaseous impurities ammonia and carbon dioxide, which are normally present in steam and which dissolve in the water formed when the steam is condensed. Even very small quantities of these dissolved gases can make a large contribution to the conductivity of the sample, and can therefore, if not removed or otherwise allowed for, render the conductivity measurement completely meaningless. For this reason, the conductometric devices most widely used at the present time contain some arrangement for removing the dissolved gases before the measurement of conductivity is made.

The simplest way of degassing the condensed steam sample is to boil it so as to drive off the dissolved gases, but the dissolved ammonia is not driven off in this way until the volume of the sample is reduced to a quarter of its initial volume, while prolonged boiling of the sample in glass vessels introduces additional errors.[14] A number of special types of degassing equipment have therefore been introduced, e.g. those due to Straub and Nelson,[15] Powell and McChesney,[16] Rivers *et al.*[17] and Janssen and Smit.[14] The disadvantages of the degasser developed by Powell and McChesney, which makes use of partial condensation at 100 deg. Cent., have been discussed in detail by Janssen and Smit. The Hagan degasser, which operates on the same principle,[17] is claimed to give a residual ammonia concentration too small to be measured when the initial ammonia concentration is in the range 2 to 3 p.p.m., but only 95 per cent removal with initial ammonia concentrations in the range 10 to 25 p.p.m. In spite of all the claims made for the various forms of apparatus, Janssen and Smit, the most recent workers in this field, expressed dissatisfaction with all of them, and developed yet another device, based on that of Straub and Nelson.[15] With this device, which contains a special type of column in which the ammonia is scrubbed out of the condensed steam, they claimed that ammonia, in concentrations much larger than those likely to be found in steam, could be completely removed. Experience with this device outside Holland is not so far available.

There is evidence that the degassing devices in use, at least until the introduction of that developed by Janssen and Smit, are not capable of removing carbon dioxide and ammonia completely from the condensed sample. It has even been suggested that this may well be impossible for ammonia.[18] In addition, Parker and Ziobro[19] have pointed out that degassing need not necessarily be complete, even at 100 deg. Cent., and that the condensate should be tested for residual carbon dioxide and ammonia so that a correction for their effect could be made.

It can, of course, be argued that completeness of removal of the dissolved gases is of no great importance since, as mentioned before, in practice, boiler operation is based merely on an arbitrary level of conductivity, without reference to its true significance in terms of salt content. The difficulty with this point of view is that, as found by Coulter and Campbell,[20] the level of carry-over from several boilers might be of the order of 0·5 p.p.m., as indicated by conductivity measurements, while in fact the extent of the deposits found in the turbines could range from zero to a magnitude such that washing or cleaning was required every few months. They also found that wide variations in boiler load or in the solids concentration of the boiler water usually failed to have any effect on the conductivity of the condensed steam samples. They were therefore led to suspect that the actual level of carry-over in most boilers was much less than that indicated by the conductivity method, and that significant changes in carry-over occurred at some low value at which this method was inaccurate. These suspicions were, in fact, confirmed by comparing the results obtained by the conductometric method with those obtained by two other methods, to be described later, which are not affected by the presence of dissolved gases. They concluded from these results that the accuracy of conductivity values below 6 micromho per centimetre was questionable, and that the inaccuracy of the method was due to the inability to remove completely, or to correct for, the residual gases in the sample.

Very similar inconsistencies in the results obtained by the conductometric method were reported by Place,[5] who found that the apparent steam purity remained constant in spite of changes in boiler rating and in the dissolved solids content of the boiler water, both of which would be expected to lead to changes in the amount of carry-over. Place also ascribed these inconsistencies to incomplete removal of dissolved gases, but possibly, in addition, to sampling system contamination. It is unfortunate that in the only reported direct comparison of the steam purity measurements made with a Hagan degasser, with those from the gravimetric and tracer techniques,[21] an ammonia-free water was used. Naturally enough, the results from all three methods of measurement were in good agreement.

To improve the accuracy of the conductometric method, the most obvious possibility would be to determine the actual amounts of the dissolved gases remaining in the sample of condensed steam after degassing, and then to apply a suitable correction, e.g. from the curves derived theoretically by Meyer and Werner,[22] instead of assuming, as at present, that degassing is always complete. One difficulty with this technique, which has been applied by Parker and Ziobro[19] is that, as these workers point out, there is lack of agreement between the various curves which have been published for the conductivity correction for the effect of dissolved gases. They have produced their own curves for this purpose, but add that there still remains a certain " area of uncertainty " related to the accuracy with which the quantities of these gases can be determined ; the difficulty of measuring accurately small quantities of dissolved gases has also been mentioned by Place.[5] Parker and Ziobro also emphasise, incidentally, that the conductivity of pure water at 100 deg. Cent. cannot be neglected in the conductivity measurements.

An alternative method of overcoming the difficulties due to the presence of dissolved gases is to produce, with simultaneous degasification, a condensed steam sample in which the concentration of the dissolved salts has been so greatly increased that the effect of dissolved ammonia on the conductivity becomes relatively unimportant. This method was first proposed by Golubtsov and Margulova[23] and a similar method has been described more recently by Gurney.[24] In the method of Golubtsov and Margulova, steam is throttled from 40 atmospheres absolute to 25 atmospheres absolute, a range of pressure in which the heat content of steam is practically constant, while outside this range the steam becomes superheated. Water is therefore produced in the form of droplets which extract the salts present in the steam, while the ammonia and carbon dioxide pass off with the uncondensed portion of the steam. The droplets are then removed in a cyclone and their conductivity measured. The only disadvantage of the method is that large quantities of steam (120–300 lb per hour) are required. The technique described by Gurney is very similar, except that he suggests that the steam should be throttled from a pressure of 30 atmospheres, and that silica, as well as salts can be removed in this way. Gurney also claims that a pressure drop of only 10 lb per square inch absolute creates sufficient moisture to give effective removal of the salts and silica.

A method of producing a condensed steam sample in which the concentration of the dissolved salts has been increased by the use of ion-exchange materials appears to have been developed in the Soviet Union by Kostrikin.[25] Unfortunately, the publication in which this method is described does not seem to be available in this country. A very brief description of the procedure is given by Chernova and Shuryushkina,[26] from which it appears that 120–250 litres of condensate are passed through a column of an ion-exchange resin called Wofatit P. This is followed by the regeneration of the resin with acid and the analysis of the acid effluent. Tests are claimed to show that absorption of the cations from the condensate by the resin is 99 per cent complete.

Ion-exchange techniques can also be used to remove the dissolved gases completely from the condensed steam sample in a process which is rather similar to that just described. The sample of condensed steam is passed through a bed of hydrogen-exchange material, as suggested by Lane *et al.*[27] and Sisson *et al.*[28] when ammonium ions are replaced by hydrogen ions according to the equation :

$$2NH_4OH + H_2Ex \rightarrow 2H_2O + (NH_4)_2Ex$$

where H_2Ex represents the " molecule " of exchange material in the hydrogen form. At the same time, of course, all the salts present in solution are converted into the

corresponding acids; in particular, hydroxides will form water and carbonates will give carbon dioxide in solution which can be removed by subsequent boiling. Thus the conductivity due to hydroxides and carbonates is lost in this process, but it is claimed that this is more then compensated for by the increase in conductivity due to the hydrogen ions, at least unless the combined hydroxide and carbonate content is greater than 50 per cent of the boiler water dissolved solids. It is also claimed that the ion-exchange technique can remove volatile amines, such as cyclohexylamine, which may be present in the steam and which have been added in order to protect the condensate system from corrosion.

One difficulty with the ion-exchange method is that it is clearly not possible to relate the final conductivity as measured to the salt content of the steam since the amounts of sodium hydroxide and carbonate present are unknown. In addition, it has been pointed out[28a] that the exchange reaction given above never goes to completion so that complete removal of the ammonia is not obtained.

In view of all the difficulties experienced with the conductometric method because of its sensitivity to the presence of dissolved gases, it might be preferable to use a technique which did not suffer from this disadvantage. Two such techniques have recently been proposed, namely, flame photometry and the use of radioactive tracers, and these are discussed in subsequent sections.

Flame Photometry.—Flame photometry is an extremely sensitive method of determining the concentration of dissolved substances, and in particular, as pointed out by Coulter and Campbell,[20] it can be used for the measurement of sodium concentrations in condensed steam samples as low as 0·0002 p.p.m. Thus it is very well adapted to use in steam purity measurement, since the boiler salts are almost invariably sodium salts, and besides the work of Coulter and Campbell it has also been employed for this purpose by Bishof *et al.*[29] and Aleksandrov *et al.*[30] As with the radioactive tracer technique to be described later, flame photometry is completely unaffected by the presence of dissolved gases in the sample. In addition, it does not suffer from the disadvantage of high cost, which would seem to rule out the radioactive tracer technique at the present time. The only difficulty connected with the method is that it is extremely vulnerable to contamination, thanks to the abundance of sodium compounds in nature. Contamination can be prevented, however, by filtering the air induced into the flame, and a filter has been described[28a] which is capable of removing 99·9 per cent of all suspended particles 0·3 micron in size. In addition, a simple type of flame photometer suitable for routine use has been developed[30a] (Fig. 3) in which a special three-channel burner is used; oxygen entering through the outer channel screens the flame from the surrounding air and thus prevents contamination by dust particles. If contamination is prevented, the method can give satisfactory results, agreeing closely with those obtained by the far more expensive radioactive tracer technique.

Radioactive Tracers.—The use of radioactive tracers in steam purity measurement has been described by Coulter and Campbell,[20] Margulova,[31] Styrikovich and Vinokur,[32] Tietz,[33] Styrikovich,[34] and Pirsh and Raynor.[34a] In essence, the method consists in adding a suitable radioactive material to the boiler water and then determining the extent of carry-over by measuring the radioactivity of the steam. The method is thus simple in principle, extremely sensitive, and completely unaffected by the presence of gaseous impurities. The only practical difficulties arise in the choice of the radioactive material to use. This depends on such factors as the type of radiation emitted, the energy of the radiation and the half-life of the material. In particular, the use of a substance emitting high energy radiation would call for a greater degree of screening of the equipment, while if a substance emitting low energy radiation, but of long half-life, is used, difficulties then arise in the disposal of waste material.

Styrikovich and Vinokur[32] used salts containing radioactive phosphorus, sulphur, sodium and calcium. They found that there was an appreciable adsorption of radioactive material on to the walls of the boiler, and it was therefore necessary to give the boiler a preliminary wash with a solution of the ordinary salt corresponding to the radioactive salt which was to be used. Apart from carrying out laboratory experiments on the tracer technique, they also worked with a semi-technical scale high-pressure boiler of volume up to 1000 litres and with vapour generation rates in the range 1–2 tons per hour. According to Styrikovich,[34] the radioactive tracer technique enables concentrations of salts in steam as low as 0·00001 p.p.m. to be measured.

Margulova[31] showed that the carry-over of phosphates and sulphates, both normal and radioactive, was directly linked with droplet carry-over, and could therefore be used to measure the steam purity. She concluded that, for the determination of steam wetness, it was most convenient to use radioactive phosphorus or sulphur, but that for determining the total salt content, radioactive sodium was preferable, since the boiler water salts are almost exclusively sodium compounds.

Although the radioactive tracer technique is extremely sensitive, it does have the practical difficulties mentioned above. In addition, its high cost makes it seem unlikely that it will be widely adopted at present.

Purity Measurement Without Sampling

If suitable measurements could be carried out on the entire steam flow, sampling, with its attendant difficulties which have already been discussed, could be avoided. One possibility would be to remove the entrained water from the steam, and then to carry out the necessary measurements on the liquid thus obtained. For this to be feasible, an entrainment separator of high efficiency would be needed, and in fact such a separator has been developed recently, on the small scale at least, by Roderick and Hierons.[35] There seems little doubt that this separator could be scaled up and used satisfactorily on a full-size plant, but unfortunately the cost of such a device would probably be so high as to make the method unattractive.

As an alternative, the measurement of suitable physical properties of the wet steam might be considered. The use of dielectric constant measurements was mentioned by Marshall,[3] but unpublished work carried out at B.C.U.R.A. has shown that this method, though possible in principle, meets with severe difficulties in practice. Another method, which is also possible in principle, is irradiation of the steam with a beam of neutrons so as to convert the sodium into a radioactive form. This has been used, for example, to distinguish between water- and oil-containing layers, on the basis of their widely different sodium contents, during the boring of oil wells.[36] A very high intensity neutron source is required, however, and even so the sodium content of the oil layer is at least 2000 p.p.m. and thus very much greater than that to be expected in steam.

The use of β- or γ-ray absorption techniques, as adopted by Isbin *et al.*[37] and Belin and Knox[11a] would seem much more promising. Isbin *et al.* used γ-ray absorption to study the void fraction, i.e. the proportion of steam in a steam/water mixture, in two-phase steam/water flow in a natural-circulation loop. Belin and Knox found that by the use of both β- and γ-rays, a very wide range of water quantities could be measured, ranging from the pipe full of water down to an equivalent thickness of 0·002in. For wet mixtures, where the equivalent water thickness exceeded 0·15in, γ-rays were most satisfactory, but for smaller thicknesses, β-rays were preferred.

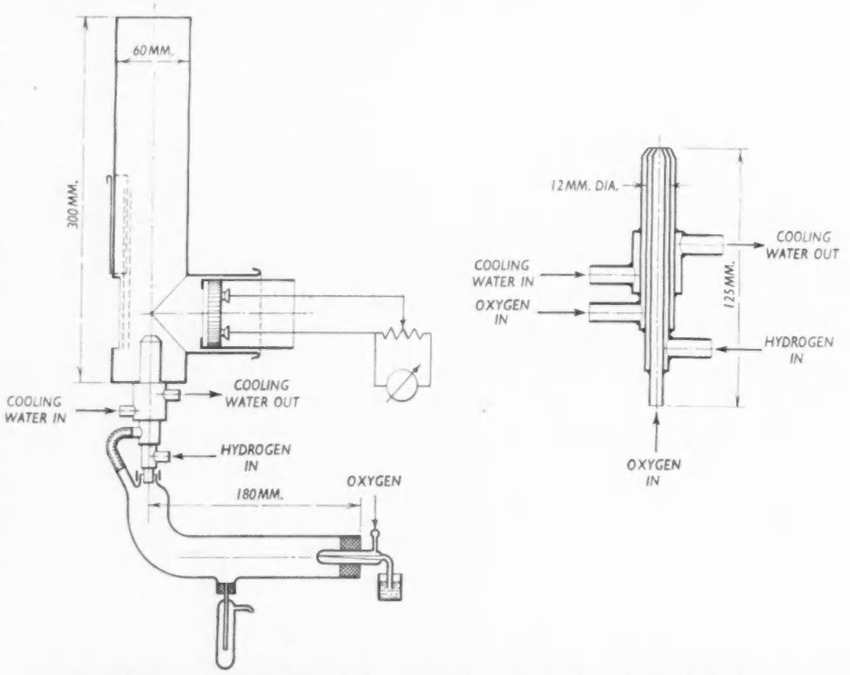


Fig. 3—Flame spectrophotometer and three-channel burner due to Korovin *et al* (Ref. 30*a*)

It should be noted that physical measurements, such as those of dielectric constant or β- or γ-ray absorption, depend on the large difference in properties that exists between steam and liquid water. For this reason they provide a direct measure only of the water content, from which the salt content must then be deduced.

Conclusions

The present review shows that the subject of steam purity measurement is not altogether in a satisfactory state. The most serious difficulty is that associated with the development of a device for obtaining a representative sample of wet steam. It is unfortunate that there has been no further information on the device mentioned by Cross[7] and that the information on the devices developed in the Soviet Union[9,12] is also insufficient. If the difficulties of sampling can be overcome, however, there seems little doubt that flame photometry, in spite of the risk of contamination of the sample, should be preferred as a method of determining the salt content in place of conductometric measurements with all their attendant complications resulting from the presence of gaseous impurities in the steam.

Acknowledgment

The assistance of Mr. D. I. J. Roderick, of the Boiler Department of the British Coal Utilisation Research Association, in the preparation of this review is gratefuly acknowledged. Mr. Roderick first drew my attention to the existence of the film of water on the pipe wall in the flow of wet steam and supplied a number of the references on which this review is based.

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Measurement of Impedance in the Audio-Frequency Range

By D. KARO, Dr. Eng., Ph.D., Dipl. Eng., M.I.E.E.*

Mainly because of the effect of residuals in the standard resistors, the number of bridge circuits that are really precision methods of measuring impedance is very limited. This article describes a novel bridge circuit in which the number of resistance standards is reduced to the barest minimum and the effect of the remaining residuals is eliminated by a double balance. One standard resistance is used for the setting of the bridge, and this is the only one in the circuit which would have a small residual.

WITH the advent of the modern detector, generally a tuned, high-gain amplifier followed by a valve voltmeter, the effect of the residuals and errors of the standards in a.c. bridge circuits became more apparent and important. The residual of an element of a circuit, such as a resistor, inductor or capacitor, is defined as the difference between the nominal value of the resistance, inductance or capacitance and the effective value, the difference being due to the phase defect of the element.

The residual of an inductance and/or capacitance standard is not such a serious matter as the residual of a standard resistance. An inductance or capacitance standard will normally have its values certified at a given frequency and mode of connection ; if the experimenter using this standard in a bridge circuit conforms to the conditions of certification, he will introduce correct effective values into the balance equations and no error will result.

Not so with standard resistances. The resistance value alone is introduced in the balance equation, the existing inductance or capacitance is not taken into account, and the balance equations are therefore false. If the residuals were introduced the equations would become too difficult and cumbersome. The problem is, of course, well known and in order to diminish the effect of the residuals a judicious disposition of the elements of the circuits, a Wagner earth and a suitable construction of resistance standards has long been practised. These remedies do not, however, eliminate the effect of the residuals completely.

By proper design and the addition of small compensating capacitors, the residual of a variable or adjustable standard resistor can be made very small for all settings, and negligibly small for some, but not zero or negligible for all settings of the dials or contacts. Adjustment of the small compensating capacitors for each dial setting would be too lengthy and cumbersome, or even beyond the scope of some industrial laboratories.

Whilst some bridge circuits are more sensitive to the effect of the residuals than others, the only simple four-arm bridge that is nearly free from their effect is the ratio bridge, provided that the residuals of the ratio arms are equal in magnitude and sign. This, in practice, means that the ratio arms have to be identical in construction and identically set ; in other words, a 1/1 ratio, or unknown equal to standard. The result is, of course, a restricted range.

The problem of measuring inductance on simple a.c. bridges without error due to residuals is more difficult than that of measuring capacitance. The ratio bridge for the measurement of inductance is not popular. A capacitor is preferable as a standard to a self-inductance and good quality variable standards of capacitance are less bulky and costly than variable standards of inductance for a similar range. In consequence, the product bridge (Hay, Maxwell) is used for the measurement of inductance. Unfortunately, the effect of the residuals is much more difficult to eliminate and generally more pronounced in the product than in the ratio bridge.

A number of bridges other than simple four-arm ones are used for measuring inductance, but they generally have a restricted range and are no more free from residuals than the ratio bridge. With the older types of detector, such as the vibration galvanometer, the headphone, the galvanometer with rectifier, and when using resistance standards with small residuals, the problem was not acute, since the effect of the residuals could be small enough to be beyond the range of the detector sensitivity. With the modern detector the sensitivity is such that a variation of $1/10^6$ or less in the variable standard is easily detected, and a great number of significant figures could, therefore, be achieved in the result of the measurement, provided, of course, that the effect of the residuals could be diminished. The logical procedure in designing a circuit for the

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measurement of impedance would therefore be to eliminate all standard resistances. Obviously this is impossible. The number of resistance standards should therefore be reduced to the barest minimum.

If the number of resistance standards is to be reduced to the barest minimum, the p.d. across the unknown resistance has to be balanced not by resistance, but by, say, an electromotive force injected by a mutual inductance. The simplest way to produce such an electromotive force would be to have the current in the branch containing the unknown 90 deg. out of phase with the current in the second branch of the bridge. It follows that the p.d. across the reactive part of the unknown will have to be balanced by an electromotive force from a second mutual inductance having its primary in series with the unknown.

As the currents in the two branches of the circuit have to be at 90 deg. to one another, presetting is required. It can be effected by placing a resistance in one branch and a mutual inductance in the other branch. The resistance used for presetting is the only standard resistance requiring to be very accurate and have a small residual. Since a presetting or first balance is made, a second balance will be required to measure the unknown and the accuracy will therefore be much improved, since the only elements influencing it are the two standard mutual inductors and the standard resistor. All bridge intercapacitances and stray couplings will have a very reduced effect.

Actual Circuit Arrangements

Measurement of an Inductive Impedance.—The circuit is shown in Fig. 1. M_1 and M_2 are the mutual inductance standards with

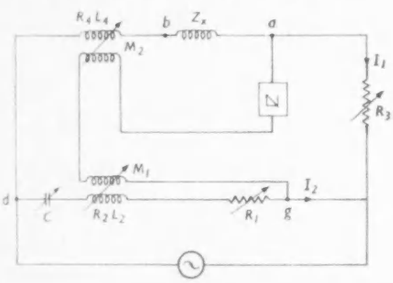

Fig. 1

very small impurities ; the primaries of M_1 and M_2 have respectively resistances R_2, R_4, and inductances L_2 and L_4 ; C is a good quality capacitance standard, R_1 a variable resistor, and R_3 a variable standard resistor.

Two balances are made.

First balance.

The detector is connected to point a, $M_2=0$; with suitable values of M_1 and R_3, C and R_1 are varied until balance is achieved, when

$$R_3I_1=-jM_1\omega I_2\ ;\quad I_1=\frac{-jM_1\omega I_2^{*}}{R_3}\quad .\quad (1)$$

Second balance :

The detector is connected to point b, M_1 is altered to M_{11} and M_2 is introduced ; no other alteration is made in the circuit.

At balance :

$$R_3I_1+R_xI_1+jL_x\omega I_1=-jM_{11}\omega I_2+jM_2\omega I_1$$

hence with (1)

$$L_x=M_2\ ;\quad R_x=\frac{M_{11}-M_1}{M_1}R_3.$$

Effect of Residuals.—The mutual inductors are assumed free from impurities, and the values of R_2, L_2, R_4, L_4 and C certified at the used frequency and method of connection

* All I's and Z's in the formulæ are complex quantities.

in the circuit. If the time constant of the resistor R_3 at a given setting is $\pm T_3$, then R_3 is, in fact, an impedance $R_3\pm jT_3\omega R_3$, and the first balance equation will result in

$$I_1=\frac{-jM_1\omega I_2}{R_3\pm jT_3\omega R_3}\quad .\quad .\quad .\quad .\quad (2)$$

In the second balance, since

$$T_3^2\omega^2R_3^2\ll R_3^2,$$

$$\frac{-jM_1\omega R_3}{R_3}-\frac{jM_1\omega R_x(R_3\mp jT_3\omega R_3)}{R_3^2}+\frac{M_1L_x\omega^2(R_3\mp jT_3\omega R_3)}{R_3^2}=-jM_{11}\omega+\frac{M_1M_2\omega^2(R_3\mp jT_3\omega R_3)}{R_3^2},$$

hence,

$$L_x=M_2\pm T_3R_x\ ;$$

$$R_x=\frac{M_{11}-M_1}{M_1}R_3\pm M_2\omega^2T_3\mp L_x\omega^2T_3$$

as

$$L_x\cong M_2;\ R_x=\frac{M_{11}-M_1}{M_1}R_3.$$

Let the time constant of R_1 at a particular setting be T_1, then R_1 is an impedance $R_1\pm jT_1\omega R_1$. Considering the arms ad and dg the first balance equation results in (with (2)),

$$\frac{M_1\omega^2L_x}{R_3}=R_1+R_2-\frac{M_1\omega^2L_4}{R_3}\pm\frac{M_1T_3\omega^2(R_x+R_4)}{R_3}$$

$$\frac{M_1\omega(R_x+R_4)}{R_3}=-L_2\omega+\frac{1}{C\omega}-M_1\omega\mp T_1\omega R_1\mp\frac{M_1\omega^2(L_x+L_4)T_3}{R_3}\quad .\quad .\quad .\quad .\quad .\quad (3)$$

whilst the second balance equation is

$$R_4I_1+jL_4\omega I_1+jM_2\omega I_1=(R_1\pm jT_1\omega R_1)I_2+R_2I_2+jL_2\omega I_2-\frac{jI_2}{C\omega}+jM_{11}\omega I_2$$

hence with (1),

$$\mp\frac{M_1T_3\omega^2R_4}{R_3}+\frac{M_1L_4\omega^2}{R_3}+\frac{M_1M_2\omega^2}{R_3}=R_1+R_2\quad .\quad .\quad .\quad .\quad .\quad (4)$$

$$-\frac{M_1\omega R_4}{R_3}+\frac{M_1T_3\omega^3L_4}{R_3}+\frac{M_1M_2\omega^3T_3}{R_3}=\pm T_1\omega R_1+L_2\omega-\frac{1}{C\omega}+M_{11}\omega.$$

Combining (4) and (3) and as $L_x=M_2$,

$$R_x=\frac{M_{11}-M_1}{M_1}R_3\ ;\quad L_x=M_2\pm T_3R_x.$$

The effect of the residuals on R_x is therefore nil and on L_x very small, especially if T_3 is small. The effect is smaller the smaller the value of R_x. In addition, there is no restriction on ratio, no identical ratio-arms are required and the calculations are easy, since the value R_3/M_1 can be set so as to be a power of ten. The measurement is extremely accurate, R_x being given in terms of the standard resistance R_3 and the values read on the mutual inductance M_1.

Change of Detector Connection.—The measurement consists of two balances and it may be remarked that the change of the detector connection from point a to point b might alter the disposition of the earth capacitance and so alter the current in the branch containing the unknown. It should be noticed, however, that the measurement of L_x is achieved entirely in the second balance by the introduction of M_2, hence, whatever the change there is no influence in the result $M_2=L_x$.

As for R_x the first balance is a presetting resulting in

$$I_1=\frac{-jM_1\omega I_2}{R_3}$$

whilst the second balance equation considering the arms ad and dg is

$$(R_4+R_x)I_1+jL_x\omega I_1+jL_4\omega I_1=(R_1+R_2)I_2+jL_2\omega I_2-\frac{jI_2}{C\omega}+jM_1\omega I_2\quad .\quad .\quad (5)$$

If the current has altered, say, from I_1 to I_{11}, then

$$(R_3+R_x)I_{11}=-jM_{11}\omega I_2\ ;\quad I_{11}=\frac{-jM_{11}\omega I_2}{R_3+R_x}$$

and the balance equation is

$$R_4I_{11}+jL_4\omega I_{11}+jM_2\omega I_{11}=(R_1+R_2)I_2+jL_2\omega I_2-\frac{jI_2}{C\omega}+jM_{11}\omega I_2\quad .\quad .\quad .\quad (6)$$

The difference between (5) and (6) is

$$jM_1\omega I_2-jM_{11}\omega I_2=(R_x+R_4)I_1+jL_x\omega I_1-R_4I_{11}-jL_4\omega I_{11}-jM_2\omega I_{11}+jL_4\omega I_1$$

hence,

$$L_x=\frac{M_{11}L_4R_3}{M_1(R_3+R_x)}+\frac{M_{11}M_2R_3}{M_1(R_3+R_x)}-L_4\quad .\quad (7)$$

$$M_1-M_{11}=-\frac{M_1(R_x+R_4)}{R_3}+\frac{M_{11}R_4}{R_3+R_x}\quad .\quad .\quad (8)$$

Substituting (7) in (8) and as $L_x=M_2$,

$$R_x=\frac{M_{11}-M_1}{M_1}R_3,$$

there is no effect on R_x either, provided, of course, that the change from I_1 to I_{11} is only a change of magnitude and does not involve a change of phase.

Measurement of a Capacitive Impedance.—The circuit is shown in Fig. 2. A variable

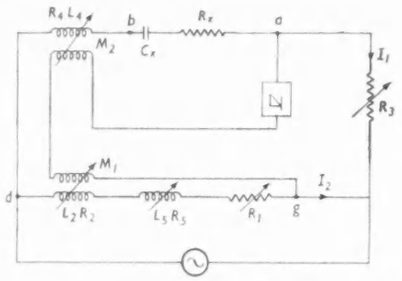

Fig. 2

inductance L_5 of constant resistance R_5 replaces the capacitance C of Fig. 1. C_x, R_x is the unknown.

First balance :

The detector is connected to point a, $M_2=0$, with suitable values of M_1 and R_3, R_1 and L_5 are varied until balance is achieved, when

$$R_3I_1=-jM_1\omega I_2\ ;\quad I_1=\frac{jM_1\omega I_2}{R_3}\quad .\quad .\quad (9)$$

Second balance :

The detector is connected to point b, M_1 is altered to M_{11} and M_2 is introduced.

At balance :

$$R_xI_1+R_3I_1-\frac{jI_1}{C_x\omega}=jM_{11}\omega I_2-jM_2\omega I_1$$

hence, with (9)

$$R_x=\frac{M_{11}-M_1}{M_1}R_3\ ;\quad \frac{1}{C_x\omega}=M_2\omega.$$

Effect of the Residuals.—The first balance with

$$I_1=\frac{jM_1\omega I_2}{R_3\pm jT_3\omega R_3}$$

results in

$$\frac{jM_1\omega R_x(R_3\mp jT_3\omega R_3)}{R_3^2}+jM_1\omega+\frac{M_1(R_3\mp jT_3\omega R_3)}{C_xR_3^2}=jM_{11}\omega+\frac{M_1M_2\omega^2(R_3\mp jT_3\omega R_3)}{R_3^2}$$

and since

$$T_3^2\omega^2R_3^2\ll R_3^2,\quad \text{hence}\quad \frac{1}{C_x}=M_2\omega^2\mp T_3\omega^2R_x$$

$$R_x=\frac{M_{11}-M_1}{M_1}R_3+\frac{T_3}{C_x}\pm T_3\omega^2M_2,$$

but

$$\frac{1}{C_x}\cong M_2\omega^2\ ;\quad \text{therefore,}\quad R_x=\frac{M_{11}-M_1}{M_1}R_3.$$

Considering arms ad and dg, the first balance equation results in,

$$\frac{M_1}{C_x R_3} = R_1 + R_2 + R_5 + \frac{M_1 L_4 \omega^2}{R_3} + \frac{M_1 \omega^2 T_3 R_4}{R_3} + \frac{M_1 \omega^2 T_3 R_x}{R_3} \quad . \quad . \quad . \quad . \quad . \quad (10)$$

$$\frac{M_1 R_x}{R_3} = T_1 R_1 + L_2 + L_5 - M_1 - \frac{M_1 R_4}{R_3} + \frac{M_1 L_4 \omega^2 T_3}{R_3} + \frac{M_1 T_3}{C_x R_3}.$$

The second balance produces

$$+\frac{M_1 \omega^2 T_3 R_4}{R_3} - \frac{M_1 L_4 \omega^2}{R_3} + \frac{M_1 M_2 \omega^2}{R_3} = R_1 + R_5 + R_2 \quad . \quad . \quad . \quad . \quad . \quad (11)$$

$$\frac{M_1 \omega R_4}{R_3} + \frac{M_1 L_4 \omega^2 T_3}{R_3} + \frac{M_1 M_2 \omega^2 T_3}{R_3} = \pm T_1 \omega R_1 + \omega(L_2 + L_5) - M_{11}\omega$$

hence, combining with (10),

$$R_x = \frac{M_{11} - M_1}{M_1} R_3 \; ; \quad \frac{1}{C_x} = M_2 \omega^2 + T_3 \omega^2 R_x.$$

There is no residual effect on R_x and a very small effect on C_x, especially if R_x is small, as is normally the case with capacitors.

There is no restriction on ratio and no identical standards of resistance are required ; the only disadvantage is the presence of the term ω^2 in the balance equations. The remarks made under " Change of Detector Connection " apply here.

Sensitivity of the Novel Bridge Circuit

If Z_3 is the standard impedance adjusted for balance in a simple four-arm bridge containing the impedances Z_1, Z_2, Z_3, Z_x, then the greatest value of the p.d. appearing across the detector, for an unbalance ∂Z_3 (that is the greatest sensitivity) is

$$dv = \frac{Z_1 E \partial Z_3}{(Z_1 + Z_2)(Z_3 + Z_x)}$$

where E is the input p.d. to the bridge.†

Let the impedances of the arms *ad* and *dg* of the circuits in Figs. 1 and 2 be denoted Z_{11} and Z_{22} respectively ; the p.d. across the detector in the first balance is zero, when

$$R_3 I_1 = \mp j M_1 \omega I_2,$$

the sign of M_1 depending on whether an inductive or capacitive impedance is being measured.

For an unbalance, there will appear across the detector a p.d.

$$v = R_3 I_1 \pm j M_1 \omega I_2.$$

As

$$I_1 = \frac{E}{Z_{11} + R_3} \; ; \; I_2 = \frac{E}{Z_{22}},$$

E being the source p.d.

$$v = \frac{E R_3}{Z_{11} + R_3} \mp j \frac{E M_1 \omega}{Z_{22}}$$

Z_{22} is varied for balance, hence

$$\frac{\partial v}{\partial Z_{22}} = \pm \frac{j E M_1 \omega}{Z_{22}^2} \; ; \quad \partial v = \pm \frac{j E M_1 \omega}{Z_{22}} \frac{\partial Z_{22}}{Z_{22}}.$$

As

$$Z_{11} I_1 + R_3 I_1 = Z_{22} I_2 = E$$

and

$$I_1 = \pm \frac{j M_1 \omega I_2}{R_3}$$

one obtains

$$\pm j M_1 \omega \frac{(Z_{11} + R_3)}{R_3} = Z_{22},$$

hence,

$$\pm \frac{j M_1 \omega}{Z_{22}} = \frac{R_3}{Z_{11} + R_3} \text{ and } \partial v = \frac{E R_3}{Z_{11} + R_3} \frac{\partial Z_{22}}{Z_{22}}.$$

The sensitivity increases, tending to

$$E \frac{\partial Z_{22}}{Z_{22}}$$

as Z_{11} diminishes which is a very desirable characteristic ; the sensitivity can always be made greater than in an ordinary four-arm bridge since the value of R_3 can be suitably altered according to the value of Z_{11}.

The second balance equation is in general,

$$R_3 I_1 + Z_x I_1 = \mp j M_{11} \omega I_2 \pm j M_2 \omega I_1$$

hence, with

$$I_1 = \frac{E}{Z_{11} + R_3} \; ; \; I_2 = \frac{E}{Z_{22}},$$

$$\frac{R_3 E}{Z_{11} + R_3} + \frac{Z_x E}{Z_{11} + R_3} = \frac{j M_{11} \omega E}{Z_{22}} + \frac{j M_2 \omega E}{Z_{11} + R_3}.$$

For an unbalance there will be a p.d. across the detector,

$$v = \frac{E(R_3 + R_x)}{Z_{11} + R_3} \pm \frac{j M_{11} \omega E}{Z_{22}} \pm \frac{j M_2 \omega E}{Z_{11} + R_3}$$

M_{11} and M_2 are altered for balance, both being independent from one another, hence,

$$\frac{\partial v_{11}}{\partial M_{11}} = \pm \frac{jE\omega}{Z_{22}} \; ; \quad \partial v_{11} = \pm \frac{j M_{11} \omega E}{Z_{22}} \frac{\partial M_{11}}{M_{11}}$$

$$\frac{\partial v_2}{v_2} = \pm \frac{jE\omega}{Z_{11} + R_3} \; ; \; \partial v_2 = \pm \frac{j M_2 \omega E}{Z_{11} + R_3} \frac{\partial M_2}{M_2}.$$

As

$$\mp j M_{11} \omega I_2 \cong (R_x + R_3) I_1 \text{ and } Z_{22} I_2 = Z_{T1} I_1$$

where

$$Z_{T1} = Z_{11} + R_3 \; ; \; \mp j \frac{M_{11} \omega}{Z_{22}} = \frac{R_x + R_3}{Z_{T1}} = \frac{R_{T1}}{Z_{T1}} = \frac{R_4}{Z_{T1}}$$

$$\cos \phi_{T1} = \frac{R_4}{Z_{T1}}.$$

TABLE I—*Results Obtained on the New Circuit*

Frequency, c/s	Certified values	Measured values	Time constant of R_3	Differential with certified values
100	L_x = 49996μH R_x = 15·89Ω	49995·7μH 15·89Ω	2×10^{-4} sec	L_x = 0·3μH R = 0Ω
500	L_x = 49996·2μH R_x = 15·89Ω	49995·9μH 15·89Ω	2×10^{-4} sec	L_x = 0·3μH R = 0Ω
1000	L_x = 49998μH R_x = 15·90Ω	49997·7μH 15·90Ω	2×10^{-4} sec	L_x = 0·3μH R_x = 0Ω
2000	L_x = 50004μH R_x = 15·90Ω	50003·7μH 15·90Ω	2×10^{-4} sec	L_x = 0·3μH R_x = 0Ω
5000	L_x = 50058μH R_x = 15·92Ω	50057·7μH 15·92Ω	2×10^{-4} sec	L_x = 0·3μH R_x = 0Ω
100	L_x = 49996μH R_x = 15·89Ω	49997·5μH 15·89Ω	$9·5 \times 10^{-4}$ sec	L_x = 1·5μH R_x = 0Ω
500	L_x = 49996·2μH R_x = 15·89Ω	49997·7μH 15·89Ω	$9·5 \times 10^{-4}$ sec	L_x = 1·5μH R_x = 0Ω
1000	L_x = 49998μH R_x = 15·90Ω	49999·5μH 15·90Ω	$9·5 \times 10^{-4}$ sec	L_x = 1·5μH R_x = 0Ω
2000	L_x = 50004μH R_x = 15·90Ω	50005·5μH R_x = 15·90Ω	$9·5 \times 10^{-4}$ sec	L_x = 1·5μH R_x = 0Ω
5000	L_x = 50058μH R_x = 15·92Ω	50059·5μH 15·92Ω	$9·5 \times 10^{-4}$ sec	L_x = 1·5μH R_x = 0Ω
100	C_x = 0·100021μF R_x = 0·3Ω	0·100021μF 0·3Ω	2×10^{-4} sec	C_x = 0 R_x = 0
500	C_x = 0·100005μF R_x = 0·13Ω	0·100005μF 0·13Ω	2×10^{-4} sec	C_x = 0 R_x = 0
1000	C_x = 0·100000μF R_x = 0·063Ω	0·100000μF 0·063Ω	2×10^{-4} sec	C_x = 0 R_x = 0

TABLE II—*Results Obtained on Simple Four-Arm Bridges*

Frequency, c/s	Certified values	Measured values	Bridge circuit	Time constant of arms	Differential with certified values
100	L_x = 49996μH R_x = 15·89Ω	49999·3μH 15·89Ω	Maxwell bridge (product bridge)	2×10^{-4} sec and $9·5 \times 10^{-4}$ sec	L_x = 3·3μH R_x = 0Ω
500	L_x = 49996·2μH R_x = 15·89Ω	49999·5μH 15·79Ω	Maxwell bridge (product bridge)	2×10^{-4} sec and $-9·5 \times 10^{-4}$ sec	L_x = 3·3μH R_x = 0·1Ω
1000	L_x = 49998μH R_x = 15·90Ω	50001·3μH 15·53Ω	Maxwell bridge (product bridge)	2×10^{-4} sec and $-9·5 \times 10^{-4}$ sec	L_x = 3·3μH R_x = 0·37Ω
5000	L_x = 50058μH R_x = 15·92Ω	50059·3μH 6·52Ω	Maxwell bridge (product bridge)	2×10^{-4} sec and $-9·5 \times 10^{-4}$ sec	L_x = 1·3μH R_x = 9·4Ω
100	L_x = 49996μH R_x = 15·89Ω	49993·0μH 15·89Ω	Hay's bridge (product)	$9·5 \times 10^{-4}$ sec	L_x = 3μH R_x = 0Ω
500	L_x = 49996·2μH R_x = 15·89Ω	49993·2μH 15·99Ω	Hay's bridge (product)	$9·5 \times 10^{-4}$ sec	L_x = 3μH R_x = 0·1Ω
1000	L_x = 49998μH R_x = 15·90Ω	49995μH 16·28Ω	Hay's bridge (product)	$9·5 \times 10^{-4}$ sec	L_x = 3μH R_x = 0·38Ω
5000	L_x = 50058μH R_x = 15·92Ω	50053·2μH 25·42Ω	Hay's bridge (product)	$9·5 \times 10^{-4}$ sec	L_x = 4·8μH R_x = 9·5Ω
100	C_x = 0·100021μF R_x = 0·3Ω	0·100021μF 1·05Ω	Ratio bridge	2×10^{-4} sec and $9·5 \times 10^{-4}$ sec	C_x = 0 R_x = 0·75Ω
500	C_x = 0·100005μF R_x = 0·13Ω	0·100005μF 0·88Ω	Ratio bridge	2×10^{-4} sec and $9·5 \times 10^{-4}$ sec	C_x = 0 R_x = 0·75Ω
1000	C_x = 0·100000μF R_x = 0·063Ω	0·100000μF 0·81Ω	Ratio bridge	2×10^{-4} sec and $9·5 \times 10^{-4}$ sec	C_x = 0 R_x = 0·747Ω

† A. C. Seletzky and L. A. Zurcher, " Sensitivity of the Four-Arm Bridge," *Electrical Engineering*, Vol. 58, pages 723–728, 1939.

therefore

$$\partial v_{11} = -E\left(\cos\phi_{T1} - \frac{R_4}{Z_{T1}}\right)\partial M_{11}.$$

Again, $M_2\omega = X_2\omega$, hence

$$\frac{M_2\omega}{Z_{11}+R_3} = \frac{X_2\omega}{Z_{T1}} = \frac{X_{T1}-L_4\omega}{Z_{T1}} = \sin\phi_{T1} - \frac{L_4\omega}{Z_{T1}}$$

and

$$\partial v_2 = +jE\left(\sin\phi_{T1} - \frac{L_4\omega}{Z_{T1}}\right)\partial M_2.$$

The sensitivities can therefore be higher than in any simple four-arm bridge.

Experimental Verification

Tests were made with certified standards on the new bridge circuits and on ordinary simple four-arm bridges. Table I shows some values obtained on the new bridge with standard resistors of varying time constant.

Table II shows some of the results obtained on some simple four-arm bridges.

Mohr Circle for Oblique Bending Deflections

By T. F. W. SMITH, B.Sc. (Eng.), A.M.I.C.E., A.M.I.Mech.E., A.F.R.Ae.S.*

A description is given of a Mohr circle for the graphical determination of oblique bending deflections and for showing the variation of deflection as the beam rotates relative to the loading. The use of the Mohr area moment circle for this purpose is also described, enabling deflections to be found graphically without reference to the principal axes.

THE Mohr circle is well known for its applications to stress, strain and second moments of area. A similar kind of circle may be derived for the deflections of a beam under oblique bending, providing not only a convenient graphical method of determining the deflections, but also a clear means of showing how the deflection varies with the rotation of the beam relative to the loading.

Derivation of Deflection Circle

Suppose a uniform beam to be bent by a given loading system so that at every cross section the bending moment is exerted about principal axis VV, as shown for an unequal angle section in Fig. 1 (*a*). Let the deflection

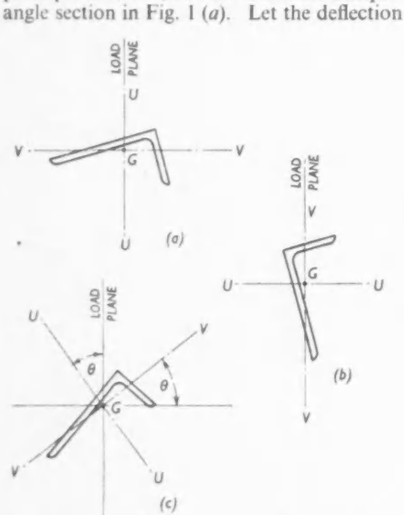

Fig. 1—Uniform beam with unequal angle section

caused at a specified section be Δ_{P_1}. Now let the beam be rotated relative to the loading until the bending moment acts about principal axis UU, as in Fig. 1 (*b*), and let the deflection at the specified section now become Δ_{P_2}. Δ_{P_1} and Δ_{P_2} may be termed the "principal deflections" for the section concerned when the beam rotates relative to the given loading system. Both these deflections are in the same sense relative to the loading and both are in the load plane, being unaccompanied by any sideways deflection. Δ_{P_1} is greater than Δ_{P_2} since the principal second moment I_u is greater than I_v.

If the beam is inclined as in Fig. 1 (*c*), having revolved anti-clockwise through angle θ from the original position when VV was perpendicular to the load plane, then the deflection at the specified section consists of a component $\Delta_{P_1}\cos\theta$ along UU and a component $\Delta_{P_2}\sin\theta$ along VV. The corresponding deflection Δ in the load plane and the sideways deflection s perpendicular to the load plane are obtained by resolution, giving :

$$\Delta = (\Delta_{P_1}\cos\theta)\cos\theta + (\Delta_{P_2}\sin\theta)\sin\theta$$
$$= \Delta_{P_1}\cos^2\theta + \Delta_{P_2}\sin^2\theta,$$

and

$$s = (\Delta_{P_1}\cos\theta)\sin\theta - (\Delta_{P_2}\sin\theta)\cos\theta$$
$$= (\Delta_{P_1} - \Delta_{P_2})\sin\theta\cos\theta.$$

These expressions may be rewritten :

$$\Delta = \tfrac{1}{2}(\Delta_{P_1} + \Delta_{P_2}) + \tfrac{1}{2}(\Delta_{P_1} - \Delta_{P_2})\cos 2\theta$$

and

$$s = \tfrac{1}{2}(\Delta_{P_1} - \Delta_{P_2})\sin 2\theta,$$

which are typical Mohr circle equations and give a Mohr deflection circle, as shown in Fig. 2, the sideways deflection s being plotted

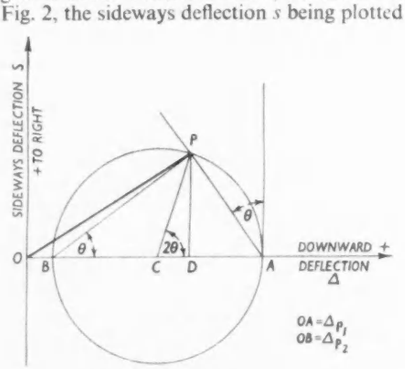

Fig. 2—Mohr deflection circle

against the downward deflection Δ for revolution of the beam relative to the loading. The circle is constructed by computing Δ_{P_1} and Δ_{P_2}, plotting them as OA and OB, bisecting AB at C and drawing the circle with centre C and radius CA. Any point P on the circle, such that angle PCA is 2θ, has co-ordinates giving the downward and sideways deflections when the principal axes are inclined at angle θ as in Fig. 1 (*c*), since

$$OD = OC + CD$$
$$= OC + CP\cos 2\theta$$
$$= \tfrac{1}{2}(OA + OB) + \tfrac{1}{2}(OA - OB)\cos 2\theta$$
$$= \tfrac{1}{2}(\Delta_{P_1} + \Delta_{P_2}) + \tfrac{1}{2}(\Delta_{P_1} - \Delta_{P_2})\cos 2\theta$$
$$= \Delta$$

and

$$PD = CP\sin 2\theta$$
$$= \tfrac{1}{2}(\Delta_{P_1} - \Delta_{P_2})\sin 2\theta$$
$$= s.$$

OP therefore gives the resultant deflection δ and angle AOP is its inclination to the load plane.

Positioning of Circle

The most convenient way of using the deflection circle is to draw it oriented as in Fig. 3, using the centroid of the section as the origin and the trace of the load plane as the Δ axis, the positive direction being

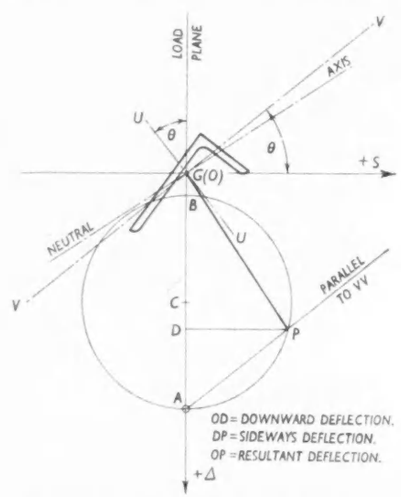

Fig. 3—Circle oriented to show true directions

downwards. With this arrangement the co-ordinates show the deflections in their actual directions and OP is, to scale, the actual displacement of the centroid. Incidentally, this locates the neutral axis which is perpendicular to OP. Fig. 4 shows a case

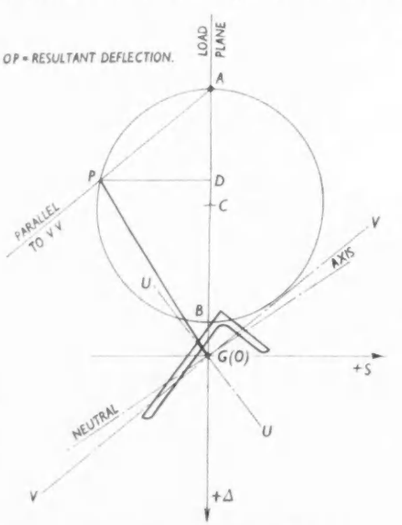

Fig. 4—Deflection circle for upward principal deflections

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where the principal deflections are upwards, the circle therefore lying above the centroid.

Use of Poles

Since the deflection circle has been derived by considering different positions of a rotating beam, it does not have the usual kind of axis pole (Reference 1). Instead, every point on the circle becomes a pole for the rotation of a corresponding axis of the section. Thus, with the orientation of Fig. 3, A is the pole for the rotation of axis VV, meaning that a line through A parallel to VV cuts the circle at the point P whose co-ordinates give the deflection components Δ and s for this position of VV. Similarly, B is the pole for axis UU. Only one pole is necessary to locate P, pole A being used in Figs. 3 and 4.

Uses of Deflection Circle

As well as the determination of deflection for a particular orientation of the section, as in Figs. 3 and 4, the circle is also useful for showing directly the necessary positions of the section to give particular deflection conditions. For example, Fig. 5 shows that

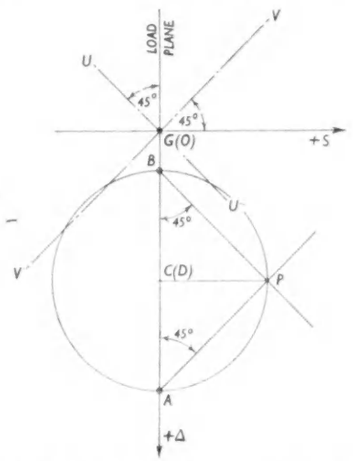

Fig. 5—Position of principal axes for maximum sideways deflection

the principal axes must be at 45 deg. to the loading to give maximum sideways deflection s, while Fig. 6 shows the position of the principal axes for the maximum leftward obliquity of the deflection to the load plane, OP being then tangential to the circle. The circle also demonstrates that the principal deflections are the maximum and minimum

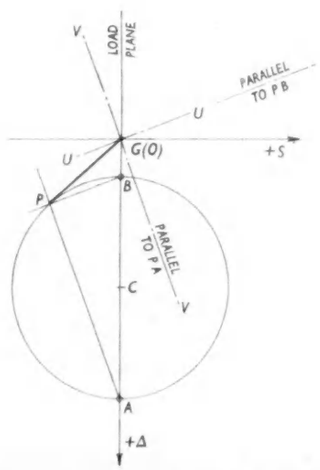

Fig. 6—Position of principal axes for maximum obliquity of deflection to loading

deflections as the section revolves relative to the loading.

Use of Area Moment Circle for Deflections

Since $\frac{\Delta_{P_1}}{\Delta_{P_2}} = \frac{I_u}{I_v}$ the Mohr area moment circle is geometrically similar to the deflection circle and may therefore be used as such, as in Fig. 7, the co-ordinates in inches[4] being multiplied by $\frac{\Delta_{P_1}}{I_u}$ to obtain the deflections. Since second moments are always positive, care must be taken to draw the circle below the centroid for downward principal deflections and above it for upward principal deflections. This use of the area moment circle saves time in plotting, as the circle can be drawn without computing deflections.

With this position of the area moment circle (that is, with the load plane trace used as the second moment axis), the point P giving the deflection coincides with the "plane pole" (Reference 1) of the area moment circle. This is the point diametrically opposite to the axis pole and is a pole through which a line parallel to any "plane of gyration" cuts the circle at a point giving the second moment for that plane. Thus, in Fig. 7,

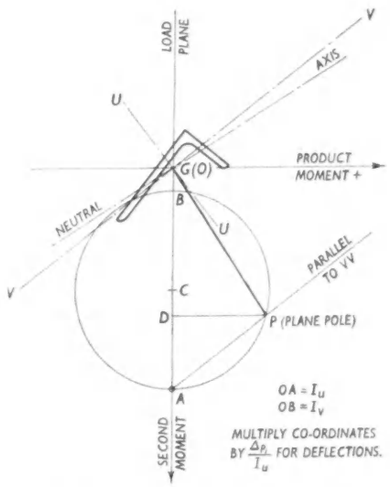

Fig. 7—Use of area moment circle for deflection

PA parallel to plane VV cuts the circle at A where $OA = I_u$, which is the second moment for gyration in the direction of plane VV (i.e. about axis UU). Similarly, PB parallel to UU would cut at B where $OB = I_v$, which is the second moment for gyration in the direction of plane UU.

Hence, having drawn the area moment circle in this position, it is only necessary to locate the plane pole P by drawing one line parallel to a plane through the appropriate point (e.g. AP parallel to VV through A in Fig. 7) and the resultant deflection δ is then immediately obtained by multiplying OP in inches[4] by the scale factor $\frac{\Delta_{P_1}}{I_u}$, the direction of δ being that of OP.

It may be noted in passing that when the area moment circle is drawn in the more usual position with the second moment axis perpendicular to the load plane, as in Fig. 8, then it is the axis pole and not the plane pole which coincides with the point P representing the deflections. In this case OP is at right angles to the actual direction of the deflection, being in the direction of the neutral axis. If the circle has already been drawn in this position to locate the neutral axis and determine the stress distribution (Reference 2), it is then only necessary to swing OP through

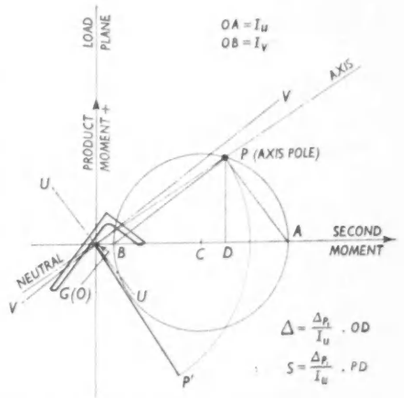

Fig. 8—Normal position of area moment circle showing deflection values given by axis pole

90 deg. to OP', as in Fig. 8, to show the true direction of the deflection.

Deflections Without Use of Principal Axes

A further advantage of using the area moment circle as a deflection circle is that it can be used to give a graphical solution of the general problem of finding the deflection relative to any pair of rectangular non-principal axes inclined to the load plane, without reference to the principal axes or principal second moments, a problem solved analytically by Levy (Reference 3). For this kind of problem it is convenient to draw the given axes XX, YY horizontally and vertically, as in Fig. 9, and to draw the area moment circle,

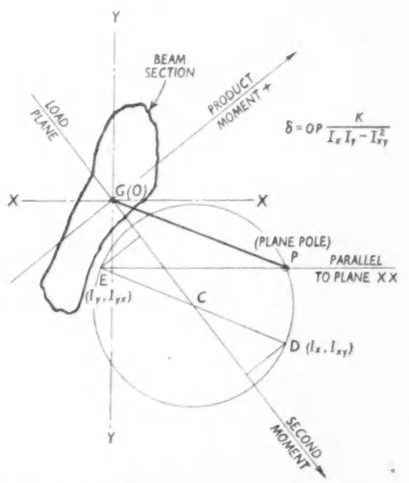

Fig. 9—Area moment circle used to find deflection without reference to principal axes

using the load plane as the second moment axis. The circle is drawn by plotting the points $D(I_x, I_{xy})$ and $E(I_y, I_{yx})$, the quantities I_x, I_y, I_{xy} being the given data for the section. The plane pole P is located by drawing either EP parallel to plane XX or else DP parallel to plane YY, the choice depending on which gives the better cut at P. OP then gives the direction of the resultant deflection δ. The value of δ could be obtained by multiplying OP by the scale factor $\frac{\Delta_{P_1}}{I_u}$ but this would involve reference to the principal axes. The scale factor can, however, be found from the given data as follows :

$$\Delta_{L_1} = \frac{K}{I_x}$$

where K is the deflection coefficient covering the effects of loading, method of support, and material (Reference 2).

Therefore, the scale factor

$$\frac{\Delta_{P_1}}{I_u} = \frac{K}{I_u I_v}$$

but

$$I_u I_v = I_x I_y - I_{xy}^2 \text{ (Reference 4)}$$

therefore the scale factor

$$\frac{\Delta_{P_1}}{I_u} = \frac{K}{I_x I_y - I_{xy}^2}$$

which can be computed from the given data for the beam and loading. Hence,

$$\delta = OP \cdot \frac{K}{I_x I_y - I_{xy}^2}.$$

Fig. 10 shows this construction used to

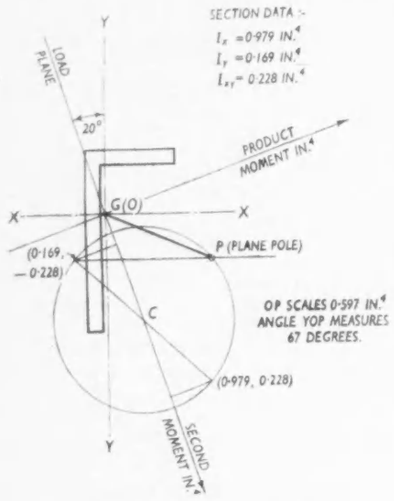

Fig. 10—Numerical example

solve the following problem : find the end deflection of an angle section cantilever 2ft long, carrying an end load of 15 lb in a downward direction at 20 deg. to axis YY, as shown. Young's modulus is 10×10^6 lb per square inch and the section particulars are $I_x = 0 \cdot 979 \text{in}^4$, $I_y = 0 \cdot 169 \text{in}^4$, $I_{xy} = 0 \cdot 228 \text{in}^4$.

It is not really necessary to draw the section itself, but it is shown in Fig. 10 for clarity. Having constructed the area moment circle and scaled OP ($0 \cdot 597 \text{in}^4$), the calculations are as follows :

Deflection coefficient for a cantilever with end load is

$$K = \frac{Wl^3}{3E} = \frac{15 \times 24^3}{3 \times 10 \times 10^6} = 0 \cdot 00691 \text{in}^3$$

$$I_x I_y - I_{xy}^2 = 0 \cdot 979 \times 0 \cdot 169 - 0 \cdot 228^2$$
$$= 0 \cdot 166 - 0 \cdot 052$$
$$= 0 \cdot 114 \text{in}^8.$$

Therefore the scale factor

$$\frac{K}{I_x I_y - I_{xy}^2} = \frac{0 \cdot 00691}{0 \cdot 114} = 0 \cdot 0606 \text{in}^{-3}.$$

Hence, deflection

$$\delta = OP \times 0 \cdot 0606$$
$$= 0 \cdot 597 \times 0 \cdot 0606$$
$$= 0 \cdot 0362 \text{in}.$$

The acute angle YOP measures 67 deg.

Thus, the deflection is 0·0362in at 67 deg. to YY, as shown.

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Free-Piston Gas Turbine Draught

By S. B. JACKSON*

The general literature of free-piston gas generators and their associated gas turbines is concerned with this simple method of power generation only, whether for land power generation or marine propulsion applications. Other applications, however, are presented. For example, the present study is concerned with the utilisation of the exhaust gas from the gas turbine as combustion air for a boiler where special considerations apply. The work is a general summary of a recent investigation in connection with the possibility of firing one oil-fuel-fired 860,000 lb per hour boiler supplying one 120,000kW turbo-alternator at the initial steam conditions of 1500 lb per square inch (g), 1000 deg. 1000 deg. Fah. reheat, and a vacuum of 29·0in (Hg).

Free-Piston Opportunities

FREE-PISTON gas generators are eminently suitable for the combustion of heavy or residual fuels both practically and economically because of their extremely high compression ratio. This is the fundamental reason for their high thermal efficiency and their low operating cost.

Without entering into a detailed statement of the advantages of free-piston gas turbine plant, suffice it to indicate that its characteristics may be of considerable value in future power station design. The fact that the plant has been tried out elsewhere denotes that it is removed from the experimental stage. When shipowners are now specifying free-piston machinery as the sole means of propulsion, that is a searching test of confidence.

It may be that any extensions of existing oil-fuel-fired power stations or new oil-fuel-fired stations could be executed on this principle.

Principles of the Free-Piston Combustion Air Scheme

It is well known that the gas output of a free-piston gas generator consists largely of unburnt air which can be employed for the combustion of large amounts of additional fuel. This principle is utilised in the case of after-burning to raise the gas temperature from the gas generator to the gas turbine, reference to which is made later.

It is now proposed that the exhaust gas from the free-piston gas turbine combination at slightly above atmospheric pressure should be employed in a preheated condition as combustion air for an oil-fuel-fired boiler. It is also suggested that the exit gas from the boiler should be used for the generation of low pressure steam and passed to the main steam turbo-alternator, by taking advantage of new knowledge which has recently become available.

The general outline of the scheme is illustrated in Fig. 1. Gas generated by the free-piston gas generators is supplied to the gas turbine after expansion through which it is used as combustion air in the boiler supplying the main steam turbine. It is suggested that the gas turbine should be in tandem with the main steam turbine to obtain unification of operation and also to assist in starting the main set. It will be necessary to increase the alternator capacity accordingly.

Consequent upon the use of this method, forced draught fans and the conventional air preheaters will be eliminated, the whole design tending towards greater capital economy, higher thermal efficiency and lower generation costs.

As the gas generators are easily controlled, they can, in conjunction with the boiler control, form part of a unified control scheme.

Steam Side Thermal Efficiency, &c.

The heat consumption of a 120,000kW machine at 1500 lb per square inch, 1000deg./1000 deg. Fah. steam conditions, 29·0in (Hg) vacuum and a final temperature of 450 deg. Fah. is approximately 8025 B.Th.U. per kilowatt hour=42·5 per cent thermal efficiency.

* Consulting Engineer.

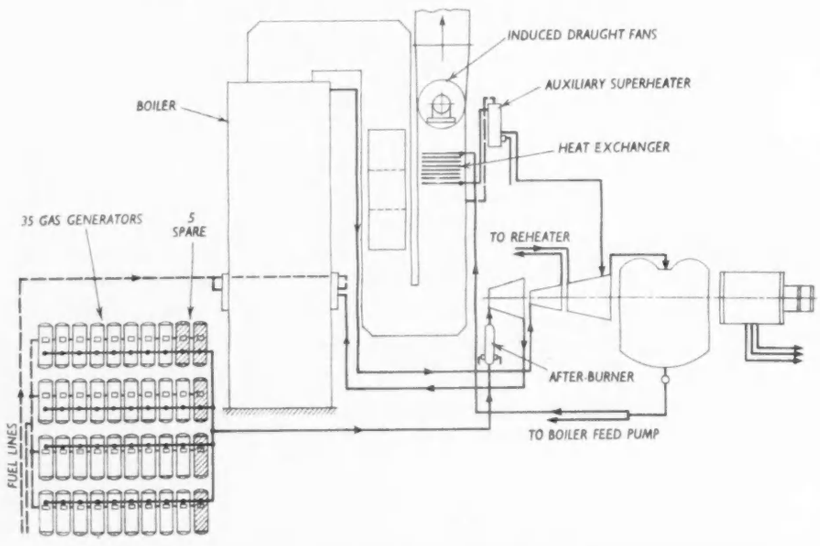


Fig. 1—Schematic layout of gas/steam cycle power station

The boiler efficiency of an 860,000 lb per hour boiler at full load can be taken as 91·0 per cent with an excess air quantity of 7·5 per cent when burning 3500 seconds heavy oil fuel, and a probable flue gas exit temperature of 320 deg. Fah. when using normal type economisers.

Putting

η_b = boiler efficiency, based on the lower calorific value of the fuel = 91·0 per cent

η_{ta} = turbo-alternator efficiency = 42·5 per cent

η_{bh} = boiler house loss factor = 96·0 per cent.

Then

$\eta_b \times \eta_{ta} \times \eta_{bh} = 91 \times 42{\cdot}5 \times 96 = 37{\cdot}2$ per cent.

Generation thermal efficiency

η_{gen} = 9160 B.Th.U./kW hour heat rate.

The station auxiliary power losses will be about 5·5 per cent, giving a station auxilaries factor η_{aux} of 94·5 per cent.

So

$\eta_{aux} \times \eta_{gen} = 94{\cdot}5 \times 37{\cdot}2 = 35{\cdot}1$ per cent overall station thermal efficiency (output) = 9720 B.Th.U./kW hour heat rate.

The calorific value of the fuel is taken as 18,500 B.Th.U./lb.

Hence

$$\frac{120{,}000 \times 9160}{18{,}500} = 59{,}500 \text{ lb/hour}$$

$$= 0{\cdot}496 \text{ lb/kW hour (generated)}$$

and

$$\frac{59{,}500}{(120{,}000 \times 0{\cdot}945 = 113{,}400)} = 0{\cdot}525 \text{ lb/kW hour.}$$

The theoretical air quantity to produce perfect combustion is 13·98 lb air per lb oil, and with the assumed excess air quantity of 7·5 per cent, 13·98 × 1·075 = 15·02 lb air per lb oil.

This gives 59,500 × 15·02 = 894,000 lb per hour air quantity required by the boiler at the conditions stated.

Free-Piston Gas Generators

The free-piston gas generator technical particulars are as follows :—

TABLE I

Thermal efficiency (into gas)	43 per cent
Output	1,250 gas h.p.
Gas pressure	45 lb per square inch (G)
Gas temperature	830 deg. Fah.
Specific fuel consumption	0·320 lb/gas h.p./hour (based on 18,500 B.Th.U./lb)
Fuel consumption/hour	400 lb/hour
Gas output	31,600 lb/hour
Cycles/minute	570
Overload rating	10 per cent for 1 hour

In respect of overload, the gas generator is similar to the diesel engine. The normal rating of 1250 gas horsepower is capable of improvement.

Suppose the same fuel is used to supply the gas generators, the theoretical air quantity to secure perfect combustion is again 13·98 lb air per lb oil.

	Lb hour
Hence, 400 × 13·98	5,590 air to consume oil fuel
Adding	400 oil fuel
	5,990 products
As the gas generator output is	31,600
Deducting products (as above)	5,990
So that the gas contains	25,610 air which can sustain further combustion
Thus the gas contains	$\frac{25{,}610 \times 100}{31{,}600} = 81{\cdot}2$ per cent pure air

which can be used for combustion purposes in the boiler.

Boiler Design Modification

It is proposed to supply the mixture to the boiler as combustion air, in consequence of which certain design modifications from normal pulverised coal or oil fuel firing are necessary. Due to higher total gas volume supplied to the boiler which amounts to the equivalent of just over 30 per cent excess air quantity, the boiler gas temperature (although preheated) will be generally lower than usual. It will, therefore, be necessary to use the lowest practicable amount of excess air to keep the temperature up with the burners located accordingly. Larger radiant heat transfer surfaces will be necessary, accompanied by appropriately increased convection and conduction surface areas. Suitable small auxiliary burners in the superheater zone would be required to maintain a high temperature in that region with the object of keeping the superheater surface area to a minimum. These departures would, however, present no great problems to the boiler designer.

It is suggested that the total oil fuel required by the boiler should be divided in the proportions : 87·5 per cent main burners, 12·5 per cent auxiliary burners. The suggested location of the latter is shown on the general layout drawing, Fig. 5.

Number of Gas Generators Required

As the total amount of air required by the boiler at 120,000kW turbo-alternator load is 894,000 lb per hour.

This can be obtained from $\frac{894{,}000}{0{\cdot}812}$

1,105,000 lb/hour gas from the gas generators. Since the gas generator output is 31,600 lb/hour we have

$$\frac{1{,}105{,}000}{31{,}600} = 35 \text{ gas generators.}$$

In the general layout, forty gas generators have been allowed for the five spare representing 14 per cent reserve capacity.

For the present purposes we are not concerned with other aspects of station operation such as overload requirements, emergencies, spare gas generator capacity, &c., all of which can be catered for in the design stage.

We will, therefore, confine discussion to the 120,000kW load condition of the steam turbo-alternator, and calculate the amount of power to be obtained from the gas generators and gas turbine to supply the combustion air for this condition.

As stated, we have

$\eta_{t\,gas}$ = thermal efficiency (gas) = 43·0 per cent

Assuming

η_{trans} = gas transmission efficiency = 99·0 per cent

η_t = gas turbine efficiency = 90·0 per cent

η_{ta} = alternator efficiency = 98·5 per cent

η_{wax} = works auxiliary factor = 98·0 per cent

Then,

Total gas h.p. per hour output × $\eta_{trans} \times \eta_t \times \eta_{ta}$

= (35 × 1250 = 43,750) × (0·99 × 0·90 × 0·985 = 0·876) = 38,300 h.p.

and

$$\frac{38{,}300}{1{\cdot}34} = 28{,}600\text{kW alternator output.}$$

With a gas turbine station works auxiliary power factor of 98·0 per cent we obtain 28,600 × 0·98 = 28,000kW gas turbine output (sent out).

The gas turbine side works power auxiliary requirements are only 2·0 per cent and are represented by gas generator water jacket cooling, lubricating oil cooling, gas turbine oil and alternator cooling and minor fuel pumping, starting air compression, &c., requirements.

We obtain

0·876 × 43·0 = 37·7 per cent thermal efficiency (generation)

and

0·98 × 37·7 = 36·9 per cent thermal efficiency (sent out)

giving

$\frac{9040}{18{,}500}$ B.Th.U./kW hour = 0·489 lb/kW hour (generated)

and

$\frac{0{\cdot}489}{0{\cdot}98}$ = 0·499 lb/kW hour (sent out)

which is slightly better performance than the steam side.

The gas turbine side fuel consumption, referred to 18,500 B.Th.U. per pound, is given by 43,750 × 0·32 = 14,000 lb per hour.

Gas Temperature Delivered to the Boiler

Making allowance for the temperature drop in the gas pipelines the gas is delivered to the gas turbine at substantially 45 lb per square inch g and 830 deg. Fah., at which condition the adiabatic heat drop is 102 B.Th.U. per pound.

With the assumed gas turbine efficiency of 90·0 per cent we obtain 102 × 0·90 = 91·8 B.Th.U. per pound turbine work.

Evaluating this performance on a gas enthalpy-entropy diagram, we obtain the exhaust gas temperature state point of 455 deg. Fah. This is shown in Fig. 2.

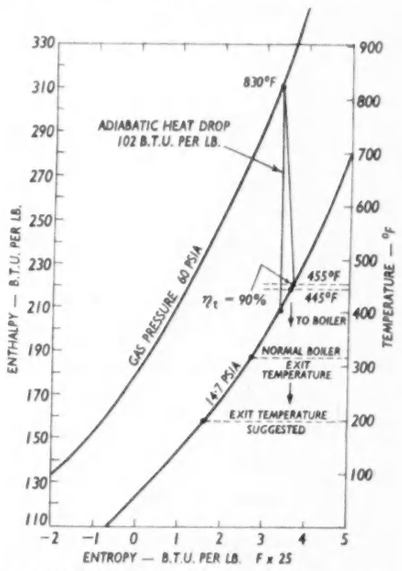


Fig. 2—Enthalpy-entropy diagram showing gas conditions at gas turbine inlet and exhaust

The gas has to be transmitted to the boiler, also at an approximate gas transmission efficiency of 99·0 per cent, and it is delivered already in a preheated condition at 445 deg. Fah.

Heat Recuperation from Boiler Exit Gas

As the combustion air from the gas turbine is already preheated, the usual air heaters in the boiler exit stage become redundant. Means must be found to replace them and to absorb the residual heat of the gas after the economiser, which is at about 530 deg. Fah. It is, therefore, proposed to recuperate the final heat via water instead of air.

The total gas delivered to the boiler is 1,105,000 lb per hour, and the boiler fuel consumption is 59,500 lb per hour.

Thus,

1,105,000 + 59,500 = 1,164,500 lb/hour products.

Normal boiler practice is to design for a boiler exit temperature for oil fuel firing of not less than 320 deg. Fah., where the sulphur characteristics of the fuel permit this.

The adoption of modern techniques based on recent research on flue gas corrosion, new concepts of economiser operation and life,

e.g. expendable sections in a low-temperature gas zone, &c., suggest that further amounts of heat may be recovered below the gas temperature of 320 deg. Fah. now current. Contemporary thought is of the opinion that the higher overall efficiency achieved at the expense of corrosion by SO_2 and SO_3 can be economically justified. It is quite possible to arrange expendable designs with the minimum of operational risk.

Due to the suggested employment of the minimum excess air quantity referred to previously, it will be appreciated that the sulphur content of the gas at exit will be at a maximum.

Considering a suggested new final temperature of 200 deg. Fah., the heat available in the gas between 320 deg. and 200 deg. Fah. will be

$$1{,}164{,}500\ (320-200\times 0\cdot 241) = 33{,}900{,}000\ \text{B.Th.U./hour.}$$

which, with generous heat transfer surface design, will produce about 28,900 lb per hour saturated steam at 55 lb per square inch (g) with feed water supplied at 80 deg. Fah. (29·0in (Hg)) straight from the condenser. Allowing for the pipe transmission losses we have available about 28,500 lb per hour (equivalent).

Additional Power from Boiler Exit Gas

This recuperated low pressure steam could be supplied at a point in the low pressure turbine stages for the generation of further power by expansion down to condenser conditions. As it will be saturated it will be necessary slightly to superheat it to obviate undue wetness at the exhaust end by cooling of the main turbine steam.

A small auxiliary independently fired external superheater is suggested for this duty. We now have

Adiabatic heat drop
55 lb/square inch (g) 350 deg. Fah.
29·0in (Hg) vacuum 315 B.Th.U./lb

Turbine efficiency τ_d down to
29·0in (Hg) vacuum 82·5 per cent

Alternator efficiency τ_{da} (as before) 98·5 per cent,

giving a steam consumption of

$$\frac{3412}{315\times 0\cdot 825\times 0\cdot 985} = 13\cdot 4\ \text{lb/kW hour,}$$

producing

$$\frac{28{,}500}{13\cdot 4} = 2130\text{kW}$$

extra power from the steam side, which corresponds to 1·8 per cent of the steam side capacity.

The additional fuel for superheating is 40 lb per hour.

This energy is obtained without the expenditure of any additional fuel except for superheating. Having regard to the simple means required in order to obtain it, it may be regarded as inexpensive.

The additional heat exchange surface would comprise gilled elements generally employed in modern gas turbine exhaust heat recuperation. It would be provided with means for chemical injection, water washing, &c., and would be constructed so as to be easily replaceable every few years.

On grounds of utilising imported fuel to the best advantage by extracting as much heat from it as possible, this proposal would appear to possess certain merits.†

† The independently-fired superheater could, alternatively, be fired from a small gas generator with after-burning at the superheater, the residue gas being taken direct to the gas turbine to do more work. Or it may be combined with the main after-burner.

Saving of Forced Draught Fans

This scheme makes it possible to dispense with boiler forced draught fans. Induced draught will be still necessary.

Estimating the forced draught power as 700 h.p. and making allowance for motor efficiency and transmission from the main busbars, we obtain a saving of about 590kW, which represents about 9 per cent of the total steam side auxiliary power requirements.

This enables not only the conservation of auxiliary power, but an additional station output of 590kW (0·52 per cent), which will possess revenue-earning capacity rather than operational loss.

Relative Station Thermal Efficiencies

The probable relative thermal efficiencies of the conventional steam station and the combined gas/steam station are now assessed.

Regarding the free-piston gas turbine layout the various values ascertained previously are collected together as shown for the evaluation in equation (2). It may be objected that the gain due to heat recuperation is available to both schemes, which is true. On the other hand, the object of this study is to ascertain the potential gains available from all sources in a station of modern design. To this extent the comparison may be considered valid.

Restating the steam station value already given, we have :

(1) Conventional steam station :

$$\frac{(120{,}000\times 0\cdot 945 = 113{,}400)\times 3412}{59{,}500\times 18{,}500} = 35\cdot 1\ \text{per cent (sent out).}$$
$$= 9720\ \text{B.Th.U./kW hour}$$
$$= 0\cdot 526\ \text{lb/kW hour}$$

(2) Combined gas/steam cycle station :

	kW
Steam side output	113,400
Exit gas recovery	2,130
Auxiliaries gain ...	590
	116,120
Gas turbine output	28,000
	144,120
	Lb
Boiler fuel	59,500
Gas turbine fuel...	14,000
Superheating fuel	40
	73,540

$$\text{Efficiency } \frac{144{,}120\times 3412\times 100}{73{,}540\times 18{,}500} = 36\cdot 2\ \text{per cent (sent out).}$$
$$= 9450\ \text{B.Th.U./kW hour}$$
$$= 0\cdot 510\ \text{lb/kW hour}$$

On the basis of 120,000kW, the fuel saved, 2·83 per cent is equivalent to 3400kW extra generated output which may be most valuable under certain operating conditions.

To attain 36·2 per cent thermal efficiency by the steam cycle would require 2000 lb per square inch, 1050 deg./1050 deg. Fah. reheat cycle approximately. There appears to be manifest thermodynamic advantages in employing the combination gas/steam cycle proposed. Of the increases in output enumerated above, only one is not directly attributable to free-piston gas turbine operation, i.e. exit gas heat recovery power.

To obtain 144,120kW output (about 153,000kW capacity) means that the alternator and exciter capacity would have to be increased accordingly. On the other hand, space limitations would require appropriate scaling down, but the results would be comparable.

Factors of Turbine Design

The low gas pressure (45 lb per square inch (g)) and gas temperature (830 deg. Fah.) to the turbine are favourable. For these conditions, the design and construction of the gas pipeline and turbine present no difficulties. There is no corrosion from vanadium when operating on low-grade fuels because the gas temperature is too low. Ferritic steels can be safely used. These are cheaper and easier to machine and have a lower coefficient of expansion than austenitic steels or other alloys employed for high temperature work. Smaller tip and gland clearances can be used, resulting in low leakage losses and high turbine efficiency.

After-Burning

Increase of the gas temperature to the gas turbine increases the output proportional to the gas absolute temperature. The increase of output referred to 28,600kW, as given previously, is shown in Fig. 3. But an actual

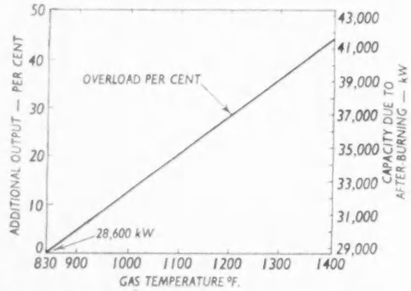


Fig. 3—Gas turbo-alternator overload output in relation to after-burning gas temperature

design would call for a gas turbine of 30,000kW capacity.

At the gas temperature of 1345 deg. Fah., corresponding to 40 per cent increased output, the total output would be 40,000kW, giving an increase of generation of 11,400kW. This equals 9·6 per cent of the output of the 120,000kW steam set and is obtained instantaneously and is not subject to boiler inertia as is the case of boiler response to increased demand.

Increase of the gas temperature due to after-burning produces an increased turbine exhaust temperature increasing the boiler preheat. As it may be expected that the demand on the steam side will be coincident with any demand occasioning after-burning, the boiler response will be accordingly increased by the increased air inlet temperature. The after-burning feature may be of considerable value in system emergency, in picking up load rapidly and accurately and also for temporary deficiencies of steam output from the boiler due to minor troubles. In order to cater for the gas temperatures referred to, obviously improved steels will be essential. Despite this, additional after-burning capacity is obtained very cheaply at about £4–£5 per kilowatt. The after-burner dimensions enable it to be housed in the engine-room. It requires no extra floor space and it would be lacking in percipience not to employ this cheap additional capacity.

It is presumed that after-burning would be regularly used during the daily load pick-up period for about one hour on each occasion. Altogether it would appear, having regard to general system operating conditions, that the total period of use of after-burning would be about 5000 hours in the life of the gas turbine, which can hardly be regarded as excessive, but which would justify the additional expenditure necessitated by this process.

Relative Station Capital Costs

A broad estimate of the respective capital costs of a conventional 120,000kW steam station with oil fuel firing and the suggested combined gas/steam cycle station is now made.

The steam station would cost about £48·0 per kilowatt capacity installed.

The combination station capacity to produce 144,120kW output would be 150,000kW.

The steam side is taken as 120,000kW in

both cases and as the overload ratings equate, no account of steam overload capacity is taken.

TABLE II—*Comparisons of Estimated Capital Costs*

	£
(1) General design :	
120,000kW at £48·0 per kW installed capacity ...	5,760,000
(2) Modified design with free-piston combustion air, 120,000kW at £48·0 per kW installed capacity :	
Less forced draught fans, ducts, rotary air heaters, &c.	
Plus special boiler design, superheater burners, small auxiliary superheater, gas generators, gas turbine, gas pipes and ducts, insulation, after-burner, heat exchanger, austenitic steels, where necessary	6,800,000

On the basis of 150,000kW capacity given above, this is equivalent to £45·3 per kilowatt installed capacity, but on the basis of after-burner rating, £41·4 per kilowatt installed capacity. The extra after-burning capacity is obtained at an actual cost of only £4 per kilowatt.

It would, thus, appear that the reduction in capital cost per kilowatt (based on £48·0 and £45·4) is about 5·5 per cent.

Relative Station Operating Costs

Estimates for the station operating costs are based on 8760 hours per annum operation at 113,400kW and 144,120kW output respectively. The various works costs are based on modern plant performance.

The main portion of the plant, i.e. the steam side, will be similar in each case. Hence, the principal constituents of works costs will be similar for both plants, as far as the steam side is concerned. It is, therefore, only necessary to add the estimated additional component costs in respect of the gas/steam cycle plant.

Detailing each item of total generation cost, we have :

(1) Capital charges are assessed as follows :

	Per cent
Interest on capital	5·0
Depreciation—25 years, equal contributions ...	4·0
Reserve and contingency allowance	1·25
Total	10·25

(2) Fuel.—A bulk price of £7 10s. per ton includes :
(3) Fuel handling allowance in respect of handling, heating, centrifuging, pumping, &c.
(4) Operation salaries and wages.—Remote centrovisory control of the gas generators is assumed. This is allowed for in the capital costs. Thus, there will be, in practice, no difference in the station operating staff required for the gas/steam cycle station.
(5) Oil, water, stores.—An increase is made in respect of gas generator and gas turbine lubrication, gas generator water jacket, cooling, &c., the assessed additional annual cost being £5000 at 100 per cent load factor.
(6) Repairs and maintenance.—Based on accumulated gas generators and gas turbine experience and including the renewal of the low pressure steam heat exchanger each 5 years, the total additional annual expenditure of £35,000 at 100 per cent load factor on this account is allowed for. This sum appears to be generous.

The aggregate result of this evaluation is given in Table III.

TABLE III—*Overall Relative Station Operating Costs*

At 100 per cent load and optimum operating conditions 8760 hours per annum.

	Conventional steam station, 113,400kW S.O.	Combined gas/steam station, 144,120kW S.O.
	£	£
1. Capital charges	590,000	696,000
2.\ Fuel (including handling,	1,735,000	2,150,000
3./ &c.)		
4. Operation, salaries, wages...	110,000	110,000
5. Oil, water stores	20,000	25,000
6. Repairs, maintenance ...	180,000	215,000
Total operating costs	2,635,000	3,196,000
Pence per kW hour S.O. ...	0·638	0·605
Saving, pence per kW hour S.O.	—	0·033
Saving, per cent	—	5·18

This evaluation does not take into account the value of after-burning capacity, which, nevertheless, has been included in the estimate of capital costs in Table II and for which capital charges are allowed in Table III.

These operating costs are shown graphically in Fig. 4, where the most convenient reference for the respective station conditions, i.e. the steam side output for both schemes, has been

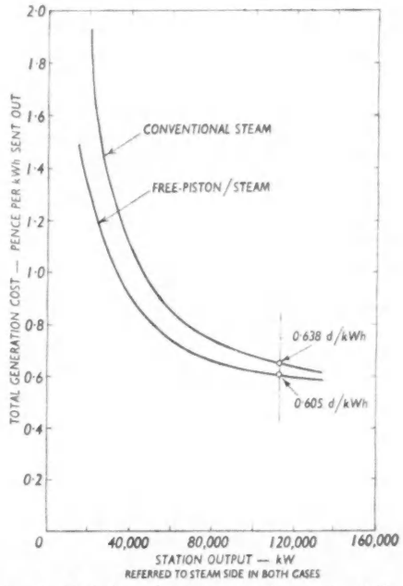


Fig. 4—Variation of total generation cost relative to steam side output

employed. At the lower loads the saving is appreciable so that during the life of the station the total economy is considerable.

The reasons for the economic advantage of the free-piston scheme are as follows :

(1) The gas generators have no stand-by losses, as is the case with boilers.

(2) Their heat conversion efficiency is high.

(3) Gas generators can be started up independently, with very small auxiliary power and starting air. They can be brought up to full load immediately.

(4) The high basic thermal efficiency into gas of 43·0 per cent.

(5) The low specific capital cost of the additional gas generators and gas turbine.

Starting the Station as a Unit

The general procedure for starting would be as follows :

(1) Prepare the steam side in the usual manner.

(2) Start circulating water pumps and vacuum production plant, &c.

(3) When ready—start induced draught fans.

(4) Open gas turbine stop valve and crack steam turbine stop valve as necessary.

(5) Start boiler feed pump.

(6) Turn on main burners to about 15 per cent full duty and superheater auxiliary burners (both with electric ignition) at about 40 per cent full duty.

(7) Start as many gas generators as may be required and run up gas turbine—run up to speed while noting the boiler steam production and operating the steam turbine accordingly.

Use either gas turbine governor or steam turbine governor for synchronising, as necessary.

The whole of this procedure would only occupy a few minutes.

Gas/Steam Station Overload Performance

So far we have considered the 120,000kW M.C.R. load condition which requires thirty-five gas generators at full load. At the usual 25 per cent overload for two hours for the steam side, the comparable conditions for the gas/steam plant are 185,800kW total station output and forty-four gas generators (without using after-burning). The gas generators have an overload rating of 10 per cent for one hour ; the suggested overload after-burning performance of the gas turbine at 1350 deg. Fah., 40 per cent and, as stated, the 25 per cent overload for two hours of the boiler and conventional steam turbo-generator. It would obviously be desirable to design the boiler, gas/steam turbo-generator, gas generators and after-burning in order to participate in the intrinsic advantages of each.

General Layout of Plant

A general layout of the plant described is given in Fig. 5, which refers only to the load and other conditions referred to previously. It does not extend to other aspects which may be relevant at the design and specification stage of a power station, as this article is only concerned with principles.

Gas Turbine Starting Technique of Main Steam Set

Without a knowledge of the basic plant design features it is not possible to expand on certain opportunities which are presented by having an ancillary gas turbine in tandem with the main steam set for rapid starting, and also to prevent risk of distortion of the various rotor components when stationary.

By using several gas generators to drive the gas turbine, it would be possible to rotate the main steam set at low speed, say 400–500 r.p.m. during off-load periods. The gas

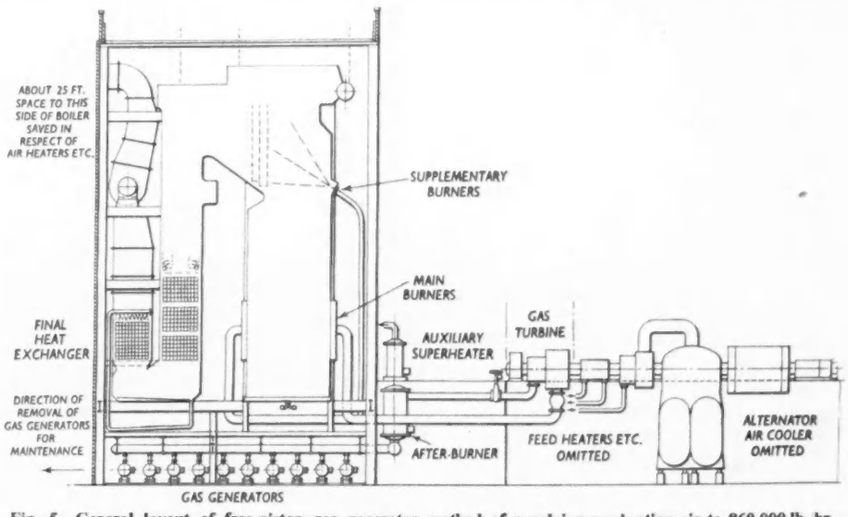

ABOUT 25 FT. SPACE TO THIS SIDE OF BOILER SAVED IN RESPECT OF AIR HEATERS ETC.
SUPPLEMENTARY BURNERS
MAIN BURNERS
FINAL HEAT EXCHANGER
AUXILIARY SUPERHEATER
GAS TURBINE
DIRECTION OF REMOVAL OF GAS GENERATORS FOR MAINTENANCE
AFTER-BURNER
FEED HEATERS ETC. OMITTED
ALTERNATOR AIR COOLER OMITTED
GAS GENERATORS

Fig. 5—General layout of free-piston gas generator method of supplying combustion air to 860,000 lb. hr, oil fuel fired boiler and 150,000 kW combined gas/steam turbo-alternator

generators can be started rapidly. While the method may be thermodynamically inefficient, it may have practical and operational advantages. Generally, however, the machine would be on two-shift duty, leaving only a short period each day under no-load running conditions. The advantage of such a technique would be to reduce the actual running-up time to synchronising speeds very considerably. It would obviously be necessary to have an auxiliary steam supply passing through the steam turbine during no-load rotation. The unit arrangement would assist this, as indeed it would also permit control of the outlet steam temperature during running-up to synchronising speed. In addition, the use of oil fuel and the flexibility it confers would be most advantageous. We need not discuss the subject further, but suffice it to note that certain possibilities exist.

The gas generators may supply an individual gas turbo-alternator in which case this discussion is inapplicable. On the other hand, this alternative arrangement would increase the capital cost in respect of the alternator, space occupation, &c.

Gas Turbine Auxiliary Power

While the discussion has been limited to a definite load condition, it will be evident that the whole of the station auxiliary power requirements could be generated with considerable advantage by the free-piston gas turbine method. It is to be observed that the thermal efficiency of the steam side is 35·1 per cent, but the employment of, say, a 6000kW gas turbine would enable the works power to be generated at about 36 per cent, giving a saving from this source of 2·6 per cent.

The ubiquity and potential reliability of the free-piston gas turbine auxiliary power generation possesses considerable attraction, for not only is it capable of generating cheap works auxiliary power, the gas can be employed for direct drives. In this connection, circulating water pumps, boiler feed pumps and the induced draught fans may be directly driven by gas turbines through modern epicyclic gearing at high thermal efficiency at the coupling, with the further advantage of heat recovery from the exhaust gas or used as boiler preheat. Standard small gas turbines from 1000 h.p. to 10,000 h.p. are available running from 17,500 r.p.m. to 3000 r.p.m. respectively.

The judicious combination of grid supplies, unit transformers from the main machine, gas turbo-alternator station auxiliary power generation, individual gas turbine drives and the great reliability of the gas generator installation would make it almost impossible to shut the station down. But if it was, it could be most readily restarted via the gas generators, gas turbine individual drives and gas turbo-alternator. The combination presents very great station reliability.

Specific Weight of Combustion Products

Amenity considerations suggest an inquiry into the relative gas conditions of two station designs :

Steam Station.—As given earlier, the products of combustion are 953,300 lb per hour at 113,400kW station output, corresponding to 8·40 lb per kilowatt sent out.

Gas/Steam Station.—In this case the total products of combustion of the gas generator fuel and the boiler fuel are 1,164,500 lb per hour at 144,120kW station output, or 8·06 lb per kilowatt sent out.

The reduction is 0·34 lb per kilowatt sent out, or 4·05 per cent.

Regarding sulphur concentration in the gases, for 1·0 per cent sulphur content in the fuel the concentration in the boiler case is 0·0625 per cent, whereas in the free-piston case it is 0·0630 per cent, an increase of just under 1 per cent.

Relative Economics

It is shown that the free-piston gas turbine station design provides :

1. More kilowatt capacity per £ capital expenditure.
2. More kilowatt hours generated per ton of oil consumed.
3. More kilowatt hours output per £ total generation cost.
4. More flexible and response operating characteristics with high instantaneous output rating.

It thus fulfils modern station economic criteria, without undue increase of size. A station with four 150,000 kW free-piston gas turbine/steam sets as described could be built at the same capital cost as a steam station with one 550,000 kW set, but it would have much greater reliability, improved operating characteristics and lower overall generation cost.

Conclusion

The well-known arguments against imported oil fuel cannot be sustained having regard to the economics and the operational attributes described which are not available to coal-fired stations. Such stations could be erected either adjacent to existing oil-fired stations or on individual sites. The capital costs of conversion of existing oil-fired stations to the scheme outlined would not be large, but the advantages would be considerable. It is believed that on this basis, the full programme of oil-fuel-fired stations would be justified. If, however, the demand for the use of indigenous resources persisted, this could be met, in part by suitable designs using coal-fired heat exchanger after-burning with normal gas turbine temperatures up to that of the steam cycle, but the disadvantages are obvious.

A trial scheme on a commercial generation basis would have the merit that the capital costs and operating costs of the gas turbine plant would be lower than those of the associated steam plant. The scheme is not too large nor too small to enable the benefits to be amply realised. Little experiment is necessary as that has already been done elsewhere. While improved gas/steam cycles are available with resulting thermal efficiencies far in excess of those indicated, because they would involve more radical departures than those described, yet based on sound engineering practice and principles, they are not put forward as they might be regarded by some as too venturesome. The scheme may, therefore, be considered a preliminary stage towards the higher thermal efficiency designs.

The scheme has, at least, an economically attractive prospect and the experience gained would prove valuable as a precursor to larger and more spectacular developments and other interesting potential applications.

Welding Fine Thermocouple Wires to Large Metal Bodies

By C. D. COLCLOUGH, Ph.D., B.Sc.(Eng.) (Rand), A.M.I.Mech.E.,* and J. SMILLIE, B.Sc.(Lond.), A.M.I.E.E.*

A portable welding unit is described which was specially designed to attach fine wire thermocouples with diameters ranging from 0·002in to 0·048in to large metal bodies. The essential advantage of the unit is that the wires can be accurately positioned by hand and this enables either single or double wire thermocouples to be welded to a wide range of components without recourse to complicated jigs or chucks. A gas discharge valve is used to initiate the weld, the energy for which is supplied by a bank of electrolytic condensers.

IN heat transfer work it is often required to attach fine wire thermocouples, with wire diameters of the order of 0·002in to 0·005in, to some comparatively large metal body. In order to measure the surface temperature of a moving body, for example, a rotating turbine blade, the thermocouples must be accurately located and the wire diameter kept as small as possible so that the change in heat and gas flow due to the thermocouple will be small. In addition, the thermocouple must be firmly attached in order to withstand the rigorous operating conditions.

The technique of brazing thermocouples to surfaces is bad, since the wires become over-heated and brittle, and it is difficult to avoid contamination of the couple materials. The possibility of distorting the parent body may also be serious. The measurement of high temperatures is especially difficult since most brazing materials will have little strength or else be limited by the melting points. The added danger of intercrystalline penetration by the brazing material and subsequent failure should this section accidentally over-heat rules out this method in the case of castings.

Peening the couple to the metal surface is not always satisfactory, particularly if the area is to be subjected to high temperatures or temperature gradients, since an oxide layer forms between the junctions of the materials and the increased thermal resistance leads to errors in the measurement of the temperature. Furthermore, the metal wall may be too thin or the metal itself may not be sufficiently malleable, and the couples might get damaged.

The most satisfactory bond is obtained by welding. It is essential that the two bodies are heated equally over the weld area, even though there is a large difference in the masses of the metals to be welded. This heating must be very rapid, so that the heat is not dissipated into the larger body, but at the same time vaporisation of the fine wire must not occur. The condenser discharge flash welding process appears to be the best.

* Parnetrada Research Station, Wallsend, Northumberland.

In this method a bank of condensers is connected in series with the wire and the body to which it is to be welded. After the condensers have been charged, the wire is brought into contact with the body, the condensers are rapidly discharged and the weld is formed. There are, however, two major difficulties in this simple system. These are the sudden discharge, which is usually violent enough to make hand operation difficult, since the operator instinctively jerks the wire away, and the high rate of cooling, which causes a rapid contraction of the materials at the point of weld and may lead to failure. To ensure that this latter does not fracture the weld it is necessary to apply pressure throughout the welding process.

In his welding set, Trott† solved these difficulties by designing a holder in the form of a spring-impelled chuck which was allowed to slide along the wire once the weld had been made and thus maintain contact without bounce. The limitations of his method were that only a single wire could be welded at a time, a separate chuck had to be made for each size of wire and, in particular, since his welding set had been designed for a specific purpose, the size of the holder precluded its use for welding thermocouples in awkward positions, such as the inside of heat exchanger tubes or between turbine blades.

The portable welding set which is described in this article has the essential advantage that the thermocouple wires can be accurately positioned by hand. This considerably extends the range of application of the instrument and enables one or more wires to be welded at a time without the need for separate or special chucks. A switching device is incorporated to initiate the weld and this reduces the tendency for violent flashes when welding, so that a technique is rapidly acquired by the operator in which there is no jerking and which appears to eliminate the need for an independent application of pressure during welding. The unit has an adjustable voltage and capacitance range so that it can be used for wires with diameters varying from 0·002in to 0·048in.

The unit has been used almost daily for the past four years and has not so far given any trouble. On two or three occasions, however, it has been found practically impossible to obtain a satisfactory weld, and since at these times the relative humidity was noted to be extremely high, it is suggested that the moisture in the atmosphere affected the contact resistance between the wire and the body.

Apart from this, several hundred successful welds have been made with wires of chromel, alumel, constantan, platinum and platinum-rhodium with wire diameters ranging from 0·002in to 0·048in. A weld is considered satisfactory if the wire has been welded normal to the surface and is then bent at right-angles adjacent to the weld without this fracturing. Trial welds in which the wire ruptures before the weld when subjected to a tensile load form the usual method of testing before final installation of the thermocouples. Reliable and consistent results have been obtained, particularly with wire diameters in the range 0·005in to 0·025in, both with single wires and double wires with the thermocouple bead preformed. Outside this range the success of the weld depends largely on trial and error and the development of a technique by the operator.

Experiments indicated that a 1000μF condenser charged to 500V would be adequate for welding 0·048in wires, but because of the violent discharge it was impossible to locate the weld accurately. The charge on the condenser is lethal in this case and careful handling is required. A circuit for welding this size of wire has been built into the unit,

† Trott, W. J., "Welder for Attaching Fine Wires to Massive Metal Bodies," *Rev. of Sci. Inst.*, Vol. 20, No. 1, January, 1949, pages 624–625.

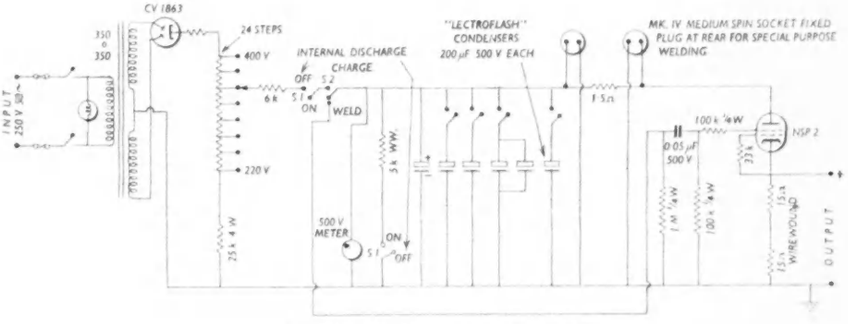


Fig. 1—Circuit diagram of welding unit

TABLE I—*Chromel and Alumel Wires Only*

Thermocouples consisting of two wires have the bead formed before spot welding

Wire diameter, in	S.W.G.	No. of wires	Capacity C μF	Volts V	Energy $\frac{1}{2}CV^2 \times 10^{-3}$
0·002	47	One	200	200	4 (resistance in series)
0·002	47	Two	200	300	9
0·0052	39	One	200	210	4·4
0·0052	39	Two	200	300	9
0·012	30	One	600	290	25·2
0·012	30	Two	800	350	39
0·020	25	One	600	350	36·8
0·020	25	Two	1400	400	112
0·025	23	One	600	400	48
0·025	23	Two	1400	400	112
0·048	18	One	1400	400	112 (flux used)

but it is not normally used and then only under the direction of a skilled operator.

Single wires of chromel and alumel 0·002in diameter have been successfully welded by interposing a suitable resistance in series with the output leads. A good weld is generally obtained for the smaller size wires when there is little or no flashing at the weld. The electrical energy required to melt the wire is proportional to the cross-sectional area of the wire. The energy dissipated at the weld point, however, depends on the resistance of the wire, the contact pressure between wire and body, size of the bead, &c., and it is difficult to determine the exact values of voltage and capacity which are required except by trial and error.

Table I, which is based on values obtained in practice, has therefore been included to indicate the approximate values of capacitance and voltage for various sizes of chromel and alumel wires.

Apparatus

A diagram of the circuit is shown in Fig. 1. Six electrolytic "Lectroflash" T.C.C. SCE60PE condensers specially developed for electronic flash tubes are used, each rated at 200μF and 500V with a capacity tolerance of −20 per cent +50 per cent. One of these is permanently in circuit and the remainder can be switched in to give even multiples of 200μF up to 1200μF. A voltage control is provided so that a wide range of energy conditions may be obtained to suit the particular gauge and material of the wires to be welded. A switch is incorporated to short the condensers through a resistor for safe handling after welding in the event of there being any residual charge.

A gas discharge valve "NSP2," made by Ferranti, Ltd., is used to initiate the weld. It was found that at the first attempt to weld an 18 s.w.g. chromel-alumel thermocouple the heavy discharge due to the low resistance path through the thermocouple caused the valve to fail. A limiting resistance of 1·5 ohms

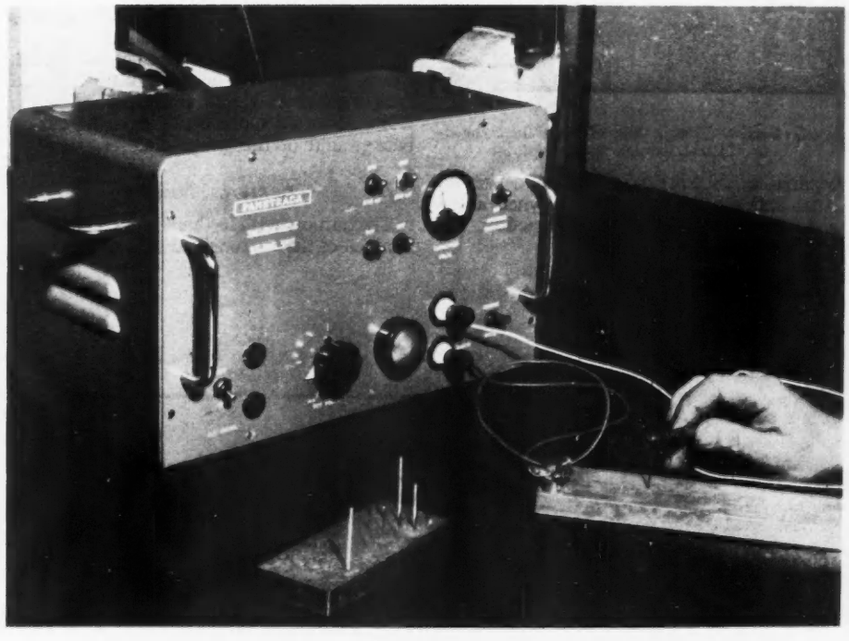


Fig. 2—Welding unit showing thermocouple wire held in position for welding

is therefore used to prevent the peak current exceeding 250A. A 30-ohm cathode resistance is also incorporated to allow a minimum discharge current of 5A should the thermocouple not be in contact with the workpiece when the unit is operated. The maximum working voltage of the " NSP2 " thyratron is limited to 400V. The energy available for welding is proportional to $\frac{1}{2}CV^2$ and should additional energy be required, provision has been made for connecting in further condensers. The lower limit of the valve voltage is fixed at 200V, which is the minimum required to operate the valve. A 200μF condenser is the minimum value of capacitance in the circuit and a series resistance would have to be used to absorb the surplus energy should the discharge energy be too great for any particular purpose.

With the " NSP2 " valve in circuit the thermocouple can be positioned exactly where required. A light clamp connects the thermocouple to the supply lead and this may be held by hand, although it is advisable to use a rubber holder (Fig. 2). Since a loss of energy takes place in the valve and the range is limited, a plug is provided at the rear inside of the unit for special purpose welding, which requires a very heavy discharge. In this case the valve is shorted out of circuit and the condensers connected directly to the wires and the metal body. Welding will take place by bringing the wire into contact with the body: a heavily insulated holder is

Fig. 3—Section through weld of 0·0052in chromel-alumel thermocouple to $\frac{1}{4}$in plate

required. Such a charge on the condensers is lethal and should only be used when absolutely necessary. Operating instructions are included in the Appendix.

The use of a relay to initiate the weld will generally result in a discharge taking place in the switch with a consequent loss of energy available for the weld. Initially, a trial circuit was made up to incorporate a " Londex " relay fitted with 900VA contacts. As expected, these were welded together on the first discharge and proved that metallic contacts were unsuitable. A 5A, 250V mercury switch was then tried. This withstood about twenty discharges of 250μF at 300V. However, at 400V, with 500μF in circuit, the glass bulb ruptured at the first discharge. The " NSP2 " which was finally used is the original valve and has been in operation for about four years.

Sections of an arbitrary number of wires which were welded to a strip of $\frac{1}{4}$in thick

Fig. 4—Section through weld of 0·012in chromel wire to steel plate.

plate are shown in Figs. 3 and 4. Fig. 3 illustrates a chromel-alumel thermocouple with 0·0052in diameter wires and a preformed bead. The two dark areas separated by a white strip immediately below the bead determined the extent of the alloy area. The black spots on the bead appear to be blow holes which may have originated when the bead was formed before welding. Fig. 4 is an enlargement of a 0·012in diameter chromel wire, 500× full size, and shows clearly that the wire material has penetrated well into the steel plate as evidenced by the white flecks interspaced amongst the darker background of the gauge plate.

ACKNOWLEDGMENT

The authors wish to thank the Director and Council of the Parsons and Marine Engineering Turbine Research and Development Association (Pametrada) for permission to publish this article.

APPENDIX

OPERATING INSTRUCTIONS

Input : 250V a.c. (5A Reyrolle inlet socket).

Output : 200–400V d.c.

The output connecting wires should be about 3A rating (23 0·0076) and reasonably short (say 5ft). If longer a higher charge may be required to compensate for lead resistance. The cable insulation should be sound and of P.V.C.

The earth lead should be connected to the workpiece and the positive lead suitably clamped to the thermocouple wires within a few inches of the couple.

The " weld " switch must not be switched to " weld " if the capacitor voltmeter reads below 200V. Failure to observe this will damage the internal thyratron switch.

The capacitor switches must not be operated until the capacitors have been fully discharged, i.e. zero reading on the capacitor voltmeter. Failure to observe this will damage the capacitor switch.

The thermocouple leads must be suitably arranged or insulated to avoid coming into contact elsewhere.

The operator should hold the thermocouple in position by means of insulated pliers or by the ceramic or other thermocouple insulation during the interval when the " weld " switch is switched to " weld."

Always leave " internal discharge " switch " ON " until ready to make a weld.

Discharge capacitors by switching " internal discharge " switch to " ON." Select value of capacitance to be used remembering that with the four selector switches " OFF " 200μF still remain in circuit.

Connect output leads and place thermocouple in position. Only lightly touch the thermocouple to the surface, since if a good electrical connection is made here, no energy will be dissipated to form a weld. Switch " weld " to " CHARGE " and " internal discharge " to " OFF." Charging will now take place. Wait until the capacitor voltmeter reaches a steady value (not less than 200V) and adjust by means of the " SET VOLTS " control. Observe the precautions stated above, then switch to " weld." Switch " internal discharge " to " ON," then if a satisfactory weld has been achieved remove output leads ; if the weld is unsatisfactory recharge and repeat above procedure. The maximum welding rate should not exceed one weld per thirty seconds.

Some Locomotives of 1909

By E. C. POULTNEY, O.B.E.

WHEN recalling British locomotive developments during 1909, now half a century ago, it will probably be safe to say that the most important events attracting attention must surely be the experimental application of three simple expansion cylinders to an express passenger engine of the "Atlantic" type by J. G. Robinson at the Gorton Works of the Great Central Railway, and the building of three-cylinder simple-expansion engines to Wilson Worsdell's designs for the North Eastern, which, as later events showed, signalled the extensive adoption of three-cylinder locomotives on this and other railways.

Recent articles contributed to THE ENGINEER, reminiscent of past locomotive practice on British lines, have recorded the introduction of locomotives of the larger types, culminating with G. J. Churchward's "Pacific" type passenger engine, "The Great Bear" of 1908. To meet, however, the diversity of requirements on a railway system such as obtained in Britain, locomotives of medium power and of varying wheel arrangements are frequently called upon; thus in 1909 examples of the well-known and eminently reliable 4–4–0 type were again designed and built.

Three examples claim notice, introduced for passenger services on the Great Western, North British and Highland lines. For the latter, P. Drummond also designed and the North British Locomotive Company built at the Queen's Park Works, Glasgow, some notably powerful six-coupled side tank engines having the 0–6–4 wheel classification and specially intended for "banking" services.

At Swindon, Churchward, continuing the development of the flue tube superheater, designed his final arrangement, which was first applied to Engine No. 4021, "King Edward," one of the four-cylinder 4–6–0 "Star" class passenger locomotives, the boiler, Swindon No. 1, being fitted for this purpose with 5in flue tubes, fourteen in number, in two rows of seven, containing eighty-four superheating pipes 1in diameter, providing 260 square feet of superheating surface. This was known as the Swindon No. 3 superheater, which remained standard for many years; in fact, it is still used for the majority of Western Region Swindon designs.

Though rather outside the main purpose of these articles, it may be of interest to call to mind some important experiments inaugurated by C. J. Bowen Cooke at Crewe, who, in 1909, had succeeded George Whale as Locomotive Superintendent of the London and North Western Railway. These early interchange trials are of special interest in view of the similar but far more extensive trials carried out in 1948. With the foregoing as a foreword to the present article devoted to locomotives of 1909, more detailed reference will now be offered to the several designs singled out for notice, commencing with some reference to development of three-cylinder engines of the simple expansion category.

THREE-CYLINDER LOCOMOTIVES

Locomotives fitted with three simple expansion cylinders have already been described in these articles recalling developments in British practice fifty years ago and as further examples of this type featured locomotives introduced during the year 1909 are of particular interest, it may not be out of place to make some reference to the earlier history of the three-cylinder locomotive which has been so largely used during recent years.

Writing in THE ENGINEER of December 12, 1952, "Notable Locomotives of 1902," and again in the issue of October 4, 1957, "Locomotive Developments in 1907," the author recalled Holden's experimental three-cylinder engine for the old Great Eastern line and the large eight-coupled 0–8–4 three-cylinder engines specially built for handling heavy shunting duties at the Wath Concentration Yards, Great Central Railway. When describing Holden's three-cylinder locomotive it was stated to be "the first modern adoption of this cylinder arrangement, being the first to have three cylinders since 1868 when one of this kind was built for the Blyth and Tyne Railway."

Though this statement may be accepted as being correct, actually, however, it is necessary to go back to the year 1882 when F. W. Webb designed and built at Crewe for the London and North Western Railway the first of the three-cylinder locomotives compounded on his system of the type and class illustrated by Fig. 1. This shows for all practical purposes the first trial engine, No. 66, "Experiment," of 1882, from which it differs only slightly in respect to the size of the cylinders and in the detail arrangement of the Joy's valve gear as applied to the outside pair of cylinders. These were the high-pressure cylinders, which exhausted into a single low-pressure cylinder between the frames and under the smokebox. Although adversely criticised in many quarters, it was these engines which in reality pioneered more modern developments in multi-cylinder locomotives and, perhaps, more especially those of the three-cylinder type, both in the Old and New Worlds. This historic fact—often overlooked—should, therefore, receive due notice, and for this reason explains why this three-cylinder design of 1882 finds a place when discussing those introduced during 1909. Webb's three-cylinder arrangement differed materially from those found in modern applications, which follow more closely Holden's experimental design of 1902, thus justifying the remarks previously made concerning this interesting locomotive.

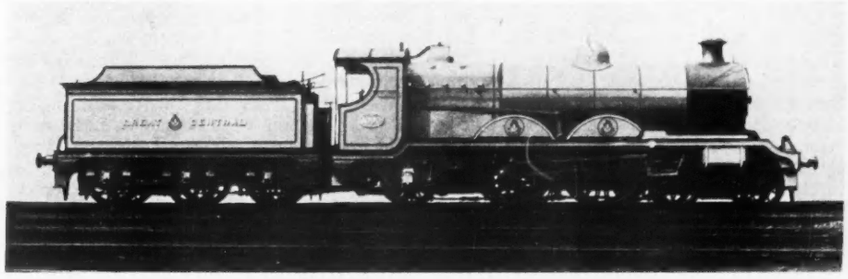


Fig. 2—Three-cylinder "Atlantic" locomotive, J. G. Robinson

No remarks on the historic development of the three-cylinder locomotive could be said to be acceptable without some reference to Sir Nigel Gresley's paper, "The Three Cylinder High Pressure Locomotive," read at the Newcastle meeting of the Institution of Mechanical Engineers, 1925, which traced the early history of the three-cylinder locomotive, first introduced by Stephenson when the initial design of 1846 appeared, followed, later, by the 1868 engine for the Blyth and Tyne Railway, as well as illustrating modern applications and discussing the advantages held to be offered by the three-cylinder system.

ROBINSON'S THREE-CYLINDER "ATLANTIC"

Three-cylinder locomotives built for the Great Central Railway at the Gorton Works, previously mentioned in these articles, reminiscent of past practice, were, it may be remembered, the four three-cylinder compounds (W. M. Smith's system), built during 1905 and 1906, and the large 0–8–4 shunting engines fitted with three simple expansion cylinders. In order to extend the use of the latter cylinder arrangement for express passenger locomotives and at the same time assimilate the design with the "Atlantic" type compounds and those of the standard two-cylinder type, one of the latter, No. 1090, was reconstructed at Gorton in 1909 as a three-cylinder simple-expansion engine,

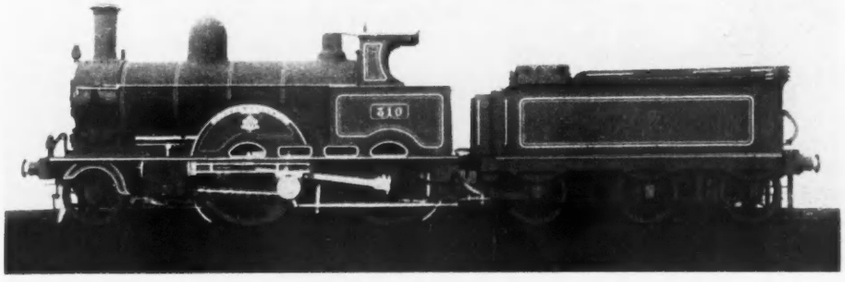


Fig. 1—F. W. Webb's three-cylinder compound engine, 1882

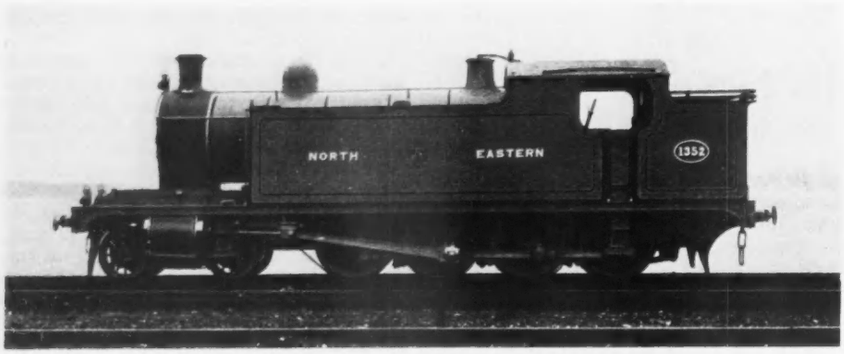


Fig. 3—Worsdell's three-cylinder locomotive, North Eastern Railway

notable as being the first modern example of this particular design for express passenger traffic. Moreover, with the completion of this locomotive, there were then available for comparison three-cylinder compounds and both two-cylinder and three-cylinder non-compounds, all of the "Atlantic" type, and also in all important respects alike.

The three-cylinder "Atlantic" No. 1090 is illustrated by the photograph, Fig. 2, for which the writer is indebted to his friend, B. Spencer, of Doncaster, who also kindly furnished an arrangement drawing showing the relative positions of the cylinders and the arrangement of the valve gears. The conversion was carried out by replacing the existing pair of 19in by 26in cylinders with three 16in by 26in, the two outside being fitted between the bogie wheels as usual, and driving the rear coupled wheels and the single centre cylinder connected with the leading pair of drivers through the medium of a single-throw crank axle of the Worsdell pattern, having circular crank webs.

The new cylinders had overhead valve chests for the slide valves, operated by three sets of Walschaerts valve gear in place of the two sets of Stephenson's gear previously used. The three expansion links were arranged in line transversely so that the radius rods could be connected through their lifting links with a common reversing shaft, and the inside set of valve gear had its eccentric rod driven by an eccentric fitted on the rear coupled axle, which enabled it to be of the same length as the outside rods which connected with return cranks as usual, with outside radial valve gears. The centre cylinder was placed slightly in advance of the outside pair, which allowed the inside connecting-rod to have a length between centres of 6ft 4in, compared with 11ft 3in for the outside rods. The principal dimensions of this notable three-cylinder locomotive, summarised below, comply with official data for the locomotive as first put into traffic. Later, the engine was fitted with a superheater which would modify the boiler heating surfaces and probably the weights.

G.C.R. Three-Cylinder "Atlantic" No. 1090

Cylinders (Three) :	
Diameter and stroke, inches	16×26
Driving wheels, diameter, inches	81
Heating surfaces, square feet :	
Tubes	1,818
Firebox	153
Total	1,971
Grate area, square feet	26·0
Steam pressure, pound per square inch	180
Engine weight, tons :	
On drivers	37
Total	73
Engine and tender	121·3
Rated tractive force, pound	18,890

North Eastern Three-Cylinder Engines

The three-cylinder locomotives built at the Gateshead Works of the North Eastern Railway from Wilson Worsdell's designs were, like J. G. Robinson's three-cylinder engines of 1907, intended principally for "hump" shunting and, although in many respects similar, differed in the wheel arrangement adopted, which was the reverse of that used for the G.C.R. engines, being of the 4–8–0 compared with the 0–8–4 type. The cylinders were arranged in line similar to the Robinson engines and, like them, had three sets of Stephenson's valve gear and a divided drive with the outside cylinders driving the second pair of coupled wheels and the centre cylinder, the leading pair through the medium of a single-throw crank axle. As will be seen from the illustration, Fig. 3, these Worsdell's engines had a particularly neat appearance, characteristic of North Eastern locomotives and, further, are of special interest as being the forerunners of others of the three-cylinder type which in later years became a distinguishing feature of North Eastern locomotive practice. The leading dimensions of these notable locomotives, taken from Sir Nigel Gresley's paper on three-cylinder simple expansion locomotives, are summarised as follow :

North Eastern Three-Cylinder Tank Engines

Cylinders (Three) :	
Diameter and stroke, inches	18×26
Driving wheels, diameter, inches	55½
Heating surfaces, square feet :	
Tubes	1,168
Firebox	127
Total	1,275
Grate area, square feet	23
Steam pressure, pound per square inch	175
Engine weight, tons :	
On drivers	67·6
Total	85·4
Rated tractive force, pound	33,900

The heating surfaces as here given differ slightly from those originally given which showed the total heating surface as being 1310 square feet and the total weight of the locomotive was also given as being 84·65 tons. For the photograph reproduced in Fig. 3 the writer is again indebted to his friend, B. Spencer, of Doncaster.

Four-Coupled (4–4–0) Locomotives

One of the most useful and generally favourite type for the diverse varieties of passenger services on British lines, the four coupled engine with a leading bogie ranked high in the esteem of traffic management and designers alike. Three examples of these engines claim attention when considering developments during 1909. Compared with Whale's "Precursor" class of 1904 and Worsdell's large engines built for the North Eastern in 1908, both of which have been noticed in these articles, those now described are relatively less powerful, but are, even so, interesting as showing how the type survived when very much larger engines were being currently introduced for passenger train requirements.

G. J. Churchward's Four-Coupled Engines

Following the introduction of his 4–4–0 type engines of the "Flower" class, built at Swindon in 1908, yet a further example of this type appeared in 1909, known as the "Bird" class, of which Fig. 4 illustrates engine No. 3733, "Chaffinch," reproduced from a photograph kindly supplied by R. A. Smeddle, the present Chief Mechanical and Electrical Engineer, Western Region, B.R. Built for lighter passenger services on the former Great Western Railway, the "Bird" class were, in reality, a smaller version of the "Flower" class, being fitted with the same standard boiler and 18in by 26in cylinders, but the coupled wheels were reduced in diameter from 80½in to 68in and, as the working steam pressure was also the same, 195 lb per square inch, the tractive effort was proportionately increased from 18,360 lb to 21,741 lb. Compared with the "Flower" class, the engine weight was 51·8 tons, as against 53·3 tons. These engines had the new form of four-wheeled leading bogie, as illustrated and described in the 1908 article of this series appearing in THE ENGINEER of November 14, 1958, when recording the building of the "Flower" class locomotives.

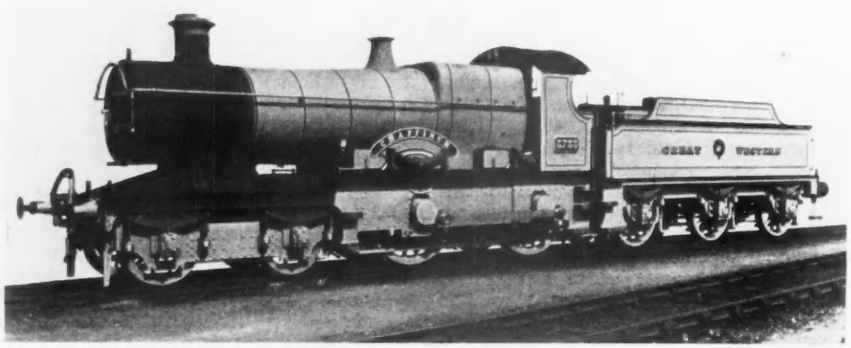


Fig. 4—G. J. Churchward's "Bird" class locomotive, Great Western Railway

The "Bird" class conformed with the following leading particulars :

G.W.R. Four-Coupled Locomotives

Cylinders :	
Diameter and stroke, inches	18×26
Driving wheels, diameter, inches	68
Heating surfaces, square feet :	
Tubes	1396·58
Firebox	121·31
Total	1517·89
Grate area, square feet	20·35
Steam pressure, pound per square inch	195
Engine weight, tons :	
On drivers	34·4
Total	51·8
Engine and tender	88·55
Rated tractive force, pound	21,741

North British Four-Coupled Locomotives

The North British four-coupled passenger engines, known as the "Scott" class, six of

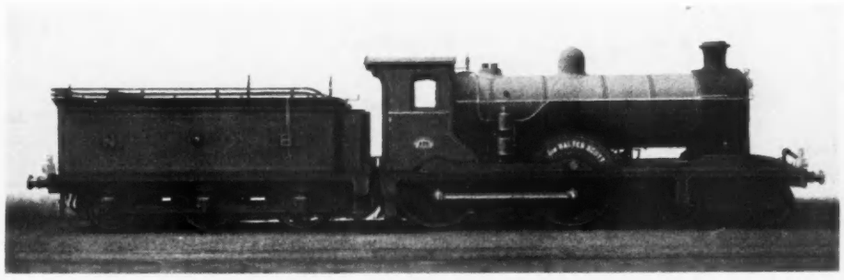


Fig. 5—North British "Scott" class locomotive, W. P. Reid

which were built in 1909 by the North British Locomotive Company, Ltd., at the Hyde Park Works, Glasgow, to the designs of W. P. Reid, represented an advance in size and power compared with previous engines of the 4–4–0 type on the North British Railway. In general, the new engines were very similar to those of the same type introduced by M. Holmes, the principal difference being the larger boilers and, as a result, some increase in weight. The relative proportions of these engines and the two latest Holmes designs, introduced in 1898 and 1903, are given in the adjoining Table I, which includes

TABLE I—*North British Railway Four-Coupled* (4–4–0) *Locomotives*, 1898–1909

	1898	1903	1907	1909
Date				
Designer	M. Holmes	M. Holmes	W. P. Reid	W. P. Reid
Cylinders, diameter and stroke, inches	18½ × 26	19 × 26	19 × 26	19 × 26
Driving wheels, diameter, in	78	78	72	78
Steam pressure, pound per square inch	175	200	180	190
Boiler heating surfaces, square feet :				
Tubes	1224	1444	1620	1478
Firebox	126	133	140	140
Total	1350	1577	1760	1618
Grate area, square feet	20·0	22·5	22·5	21
Engine weight, tons	47	52	55	54·8
Rated tractive force	16,460	20,440	19,920	19,460
Class	"729"	"317"	"19in intermediate goods"	"Scott"

similar particulars of an intermediate class, also of the 4–4–0 type, built to W. P. Reid's design in 1907 and intended for mixed traffic purposes. The first two examples are the last built to the designs of M. Holmes, those of 1903 coming out just prior to his retirement and the appointment of W. P. Reid as Locomotive Superintendent.

A point of some interest in the Holmes engines is their great similarity to the McIntosh "Caledonian" engines of 1896 and 1903, and the same remark applies also to Reid's "Scott" class, which resembled in many respects the McIntosh "140" class, built in 1904. If reference is made to the tabulated dimensions of the "Caledonian" engines given in THE ENGINEER of October 8, 1954, "Notable Locomotives of 1904," the striking likeness between these 4–4–0 type engines will be clearly seen. For the accompanying photograph, Fig. 5, of the "Scott" class locomotive No. 898, "Sir Walter Scott," one of the first six built, the writer is indebted to the North British Locomotive Company, Ltd.

In order to harmonise with the dimensions given of other locomotives included in this survey of those built in 1909, the following are particulars not included in the Table I, "Scott" class, N.B. Railway.

Weights, tons :	
Engine :	
On drivers	36·4
Total	54·8
Engine and tender	100·8

NEW LOCOMOTIVES FOR THE HIGHLAND LINE

Locomotives introduced by Peter Drummond for the Highland Railway embraced two different types, one a 4–4–0 design for passenger traffic and the other a side tank of the 0–6–4 type, representing powerful locomotives intended principally for "banking" purposes on the steep grades abounding on the Highland Line. Strictly speaking, the passenger engines as a design were not new in 1909 because, as a matter of fact, they first appeared the year before, 1908. They were, however, added to during 1909 and, like those introduced earlier, came from the North British Company, Ltd. As a design, these engines resembled in many respects some of the same type for passenger services, constituting Peter Drummond's first engines for the Highland. These came out in 1898, two years after Drummond's appointment as Locomotive Superintendent in 1896. These earlier locomotives, which set the pattern for Peter Drummond's 4–4–0 Highland engines, were typical of the Drummond design first built by Dugald Drummond for the North British and, later, for the Caledonian Railway and, as such, were completely different from many of the Jones Highland 4–4–0 locomotives, which, with their "outside" cylinders and in other respects, were typical examples of the original Allan design, initiated at Crewe in 1844. P. Drummond, however, on his appointment, following his brother's example, employed "inside" cylinders and Stephenson's valve gear, the latter replacing the Allan straight link gear used by Jones. In most respects, Drummond's 4–4–0 engines resembled, as already mentioned, the well-known Drummond standard pattern, which reappeared at Nine Elms when D. Drummond succeeded W. Adams as Locomotive Superintendent of the London and South Western in 1896. Continuing with the Peter Drummond engines, those of 1898 were known as the "Ben" class and the latter design, introduced in 1908 and again built in 1909, were called "Big Bens" on account of their larger proportions. One of the 1909 series is illustrated by the photograph, Fig. 6, of engine No. 60, "Ben Bhreac Mhor," supplied for this article by the makers. These later locomotives differed from the earlier 1908 engines, received from the same makers, by being fitted with larger tenders of the eight-wheeled, double bogie pattern, with 3500-gallon tanks and a full weight of 39·5 tons. So far as the cylinders and motion are concerned and in the size of the coupled wheels, all the "Bens" were alike, but the "Big Bens" differed from the 1898 engines by being provided with much larger boilers, having more heating surface, totalling 1648 square feet as against 1175 square feet for the first "Ben" class engines. In addition, the later engines had a small increase in the working steam pressure of 180 lb, comparing with 175 lb per square inch.

The leading dimensions of the later "Big Ben" class, with the eight-wheeled tenders, are as follow :

Highland Railway "Big Ben" Locomotives

Cylinders :	
Diameter and stroke, inches	18½ × 26
Driving wheels, diameter, inches	72
Heating surfaces, square feet :	
Tubes	1516·2
Firebox	132·0
Total	1648·2
Grate area, square feet	20·3
Steam pressure, pound per square inch	180
Engine weight, tons :	
On drivers	35·2
Total	52·3
Engine and tender	91·8
Rated tractive force, pound	18,360

THE 0–6–4 TANK ENGINES

Drummond's powerful side tank engines, specially designed for "banking" duties, are illustrated by the photograph, Fig. 7, of No. 39, supplied, as previously mentioned, by the builders, the North British Locomotive Company, Glasgow. They represent an outstanding example of a somewhat uncommon type compared with similar engines of the much more numerous 0–6–2 type. The trailing four-wheeled bogie in place of the single radial axle box, or Bisel truck arrangement used for the latter design, has the advantage of enabling a bunker of larger capacity being provided, which, in the case of the Highland engines, carried as much as 4·5 tons of coal, which with 2000-gallon tanks gave these engines a relatively large radius of action and sphere of usefulness. Four of these engines were placed in service during 1909, followed by a further four in 1910 and 1912. The design in general may be said to conform with normal practice of the period : thus, they had "inside" cylinders fitted with slide valves operated by Stephenson's valve gear. With cylinders 18½in by 26in, 60in coupled wheels and a working steam pressure of 180 lb per square inch, the rated tractive force was 22,200 lb and, as the weight on the coupled axles was

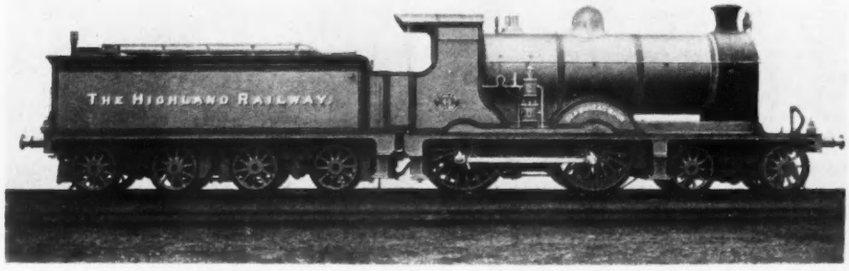


Fig. 6—P. Drummond's "Big Ben" class locomotive, Highland Railway

Fig. 7—Highland Railway 0-6-4 tank engine

109,760 lb, the factor of adhesion came out at 4·94, so that they would no doubt be well able to utilise their high tractive force, an important factor for engines required for "banking" purposes over the heavy grade sections found on the Highland lines.

The leading dimensions of these locomotives are tabulated as follow :

Highland Railway 0-6-4 *Tank Engines*

Cylinders :	
Diameter and stroke, inches	18½ × 26
Driving wheels, diameter, inches	60
Heating surfaces, square feet :	
Tubes	1148
Firebox	120
Total	1,268
Grate area, square feet	22·43
Steam pressure, pound per square inch	180
Engine weight, tons :	
On drivers	49
Total	69·5
Rated tractive force, pound	22,200

The Swindon Superheater

After several experimental applications of flue tube superheaters, the design of the Swindon No. 3 superheater was finished in 1909, and applied, as already mentioned, to a standard No. 1 boiler. The special design of the Swindon superheater will not be gone into now ; it has been fully illustrated in The Engineer and, while considered to have desirable features, its use has been practically entirely confined to Swindon-built locomotives. The accompanying photograph (Fig. 8), shows one of the standard No. 1 boilers of the latest form of construction as fitted with the superheater and the top feed arrangement, which became standard about 1910 or 1911.

The fitting of the superheater necessarily altered the tube arrangement of the standard No. 1 boiler as first designed for saturated steam, and the adjoining Table II has been

Table II—*Great Western Railway : Dimensions of Standard No. 1 Boiler*

Saturated and superheated steam
Working steam pressure 225 lb per square inch

	Saturated	Superheated
Tubes, number	250	176
Tubes, diameter outside, inches	2	2
Tubes, length, feet inches	15 2⅝	15 2⅝
Tubes, heating surface, square feet	1988·65	1411·52
Flues, number	—	14
Flues, diameter outside, inches	—	5½
Flues, length, feet inches	—	15 2⅛
Flues, heating surface, square feet	—	275·08
Firebox, heating surface square feet	154·26	154·78
Total heating surface, square feet	2142·91	1841·38
Superheater, Swindon No. 3 :		
Tubes, number	—	84
Tubes, diameter outside, inches	—	1
Tubes, length, feet inches	—	15 3½
Heating surface, square feet	—	262·62
Heating surface, square feet Combined	—	2104·00
Grate area, square feet	27·09	27·09

Length of tubes and flues is the distance between tube plates.

prepared giving particulars of the tube arrangements and heating surfaces of the boiler with and without the superheater. Information applying to the No. 1 boiler when originally designed is as given by G. J. Churchward in his paper, "Large Locomotive Boilers," Institution of Mechanical Engineers, 1906, and for the superheater boilers the particulars given apply to those more recently fitted to modern Swindon engines.

London and North Western Railway : Locomotive Interchange Trials

Shortly after being appointed Locomotive Superintendent of the London and North Western Railway in succession to George Whale in 1909, C. J. Bowen-Cooke instigated a series of locomotive exchanges for the purpose of obtaining a direct comparison of the working of North Western engines and those of other railways under equal running conditions.

While, as already stated, this phase of locomotive development is somewhat outside the purpose of these articles, some reference may be admissible to these interesting experiments, which will be confined to the comparative performance of North Western and Great Northern passenger engines. These trials, which were carried out in June, 1909, were specially interesting because they indicated the relative performance of two engines of the four-coupled type, one with the 4-4-0 wheel arrangement and the other of the 4-4-2 "Atlantic" design. So far as cylinder power is concerned, there was little difference between these engines, but the "Atlantic" had, by reason of its wheel arrangement, considerably more boiler capacity. How this influenced performance under the same operating conditions could, therefore, be judged from the performance of these locomotives.

Scope of the Tests

The locomotives involved in these trials were the 4-4-0 "Precursor" class engines, No. 510, "Albatross" and No. 412, "Marquis" and the Great Northern wide firebox "Atlantics," Nos. 1449 and 1451. Both these locomotive classes have been fully described in these articles ; it may, however, be advisable to mention that the 4-4-0 North Western engines had 19in by 26in cylinders, 81in drivers, 1962 square feet of heating surface and 22·4 square feet of grate area, the full locomotive weight being 96·75 tons, and the Great Northern "Atlantics" had 18½in by 24in cylinders, 79½in drivers, 2500 square feet of heating surface, 30·9 square feet of grate area and a full locomotive weight of 111·5 tons. The tests on the London and North Western were made between the "Precursor" class engine "Albatross," No. 510, and the Great Northern engine No. 1449.

Most of the runs consisted of journeys between London and Crewe with the 10.0 a.m. Scotch express, returning from Crewe with the fast Liverpool express, the 5.2 p.m. ex Lime Street, due at Euston at 8.10 p.m. On the Great Northern, the "Precursor" class engine, "Marquis," No. 412, worked several journeys between Doncaster and Leeds, Leeds and London (King's Cross), and also between London and Doncaster. The total weekly mileage amounted to 2050 miles, the competing "Atlantic," No. 1451, making the same number of trips with approximately equal train loads and average speeds.

The Performance of the Locomotives

Some interesting results of these experimental journeys are presented by Tables III and IV. The data given are based on official particulars published in an informative article by O. S. Nock, writing in *The Railway Magazine*, November, 1936. The tabulated statements presented give these results in a slightly modified form. The working of the two engines on the London and North Western Railway is given by Table III, which is divided into two sections, one giving some results of a single journey from London to Crewe with the 10.0 a.m. Scotch express when a dynamometer car

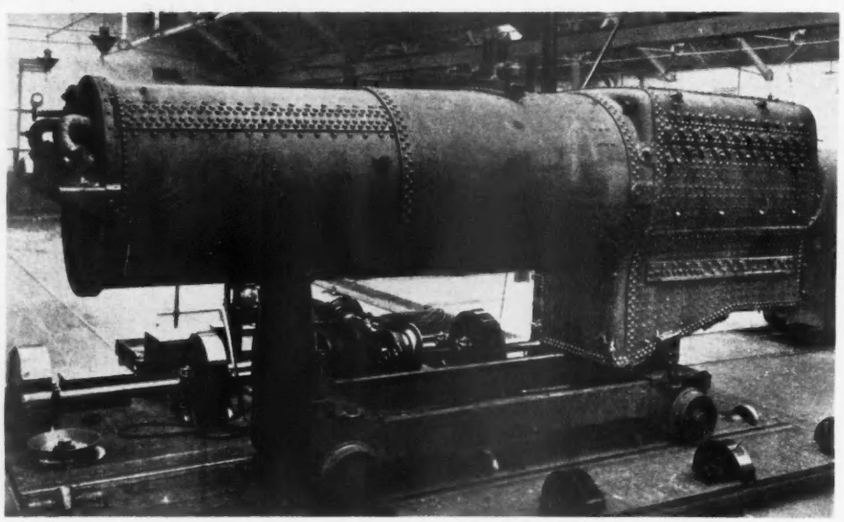


Fig. 8—Churchward's superheater No. 1 boiler

was included in the train, and the other section the mean results of all journeys aggregating upwards of 1,000,000 net (train) ton-miles for each locomotive.

The following statement (Table IV), gives the mean results of the journeys from Doncaster to London (King's Cross), and returns a total of 314 miles for the double trip. In the case of these runs over the

TABLE III—*L.N.W.R.–G.N.R. Locomotive Interchange Trials*, 1909

10.0 a.m. Euston–Crewe, 158·1 miles

Locomotive	L.N.W.R. "Precursor" class No. 510 "Albatross"	G.N.R. "Atlantic" "251" class No. 1449
Train load, tons (tare)	399	398
Maximum drawbar pull, starting, tons	8·5	9·125
Journey time, min	186	186·75
Running time, min	179·5	180·75
Average speed, m.p.h.	52·9	52·5
Running time: Maximum speed, m.p.h.	70	73
Average results all journeys on L.N.W.R.		
Train load, average, tons	290	320
Number of journeys	26	26
Train-miles, total	4113	4113
Train ton-miles, total	1,194,250	1,317,448
Coal fired per train-mile, lb	40·73	41·08
Coal fired per train ton-mile, lb	0·140	0·128

Great Northern, the data are rather more complete, as they include the mean speeds in miles per hour as well as the coal-fired pound per mile. In the case of the test runs on the Great Northern, it is stated that Houghton coal was employed. These test results for the journeys on the London and North Western and on the Great Northern

TABLE IV—*L.N.W.R.–G.N.R. Locomotive Interchange Trials*, 1909

Results of trips between King's Cross and Doncaster

Locomotive	G.N.R. "Atlantic" class "251," No. 1461	L.N.W.R. "Precursor" class No. 412 "Marquis"
Number of trips, King's Cross to Doncaster and return	16	16
Miles per double journey	312	312
Average train load, tons	237·75	236·5
Average speed, m.p.h.	53·12	52·73
Total ton-miles train only	1,202,068·4	1,184,744
Coal fired, lb per train-mile	34·6	36·5
Coal fired, lb per train ton-mile	0·145	0·154
Coal fired, lb per hour	1837·9	1924·6
Coal fired, lb per square foot of grate area per hour	85·9	59·4

show the "Atlantic" to be the more economical of the two engines in coal consumption. Measured on the net ton-mile basis, the "Atlantic" shows an economy of 9 per cent on the London and North Western and, on the Great Northern, of about 6 per cent. Assuming the same average powers were developed with substantially equal train loadings and at closely equal mean speeds miles per hour, it is evident that the power required in relation to the boiler heating surfaces and in relation to the area of the grate would be much less in the case of the "Atlantic" with its much larger boiler. This would increase the evaporation efficiency compared with the smaller boiler of the 4–4–0 locomotive.

On the Great Northern, the average rates of firing appear to have been 1837·9 lb per hour for the "Atlantic" and 1924·4 lb per hour for the 4–4–0 locomotive, equal to a firing rate of 59·4 lb of coal per square foot of grate area per hour for the "Atlantic" and 85·9 lb per hour for the 4–4–0 engine, representing an increase of as much as 45 per cent. This higher rate of firing would probably mean a fairly considerable fall in the efficiency of the smaller boilers, the decrease depending on the rate of fall shown by the efficiency characteristic with advancing rates of firing. Referring to the coal consumptions per ton-mile, these, it should be noted, are given on the basis of the train weight only; in other words, on the net ton-mile basis and not, as is more common, the gross ton-miles. They are not really comparable with the figures given for more recent trials.

Internal Combustion Engine Research

RECENTLY The British Internal Combustion Engine Research Association held open days at its laboratory at Buckingham Avenue, Slough, in order to demonstrate the range of present investigations and the scope of its research activities, all designed to improve the efficiency and reliability of diesel engines. Particular attention was drawn to specific items currently in progress, and during a tour of the laboratory, members of the staff, responsible for the various individual research programmes, each briefly explained the object of the research and described both the equipment employed and the technique developed to obtain the data required.

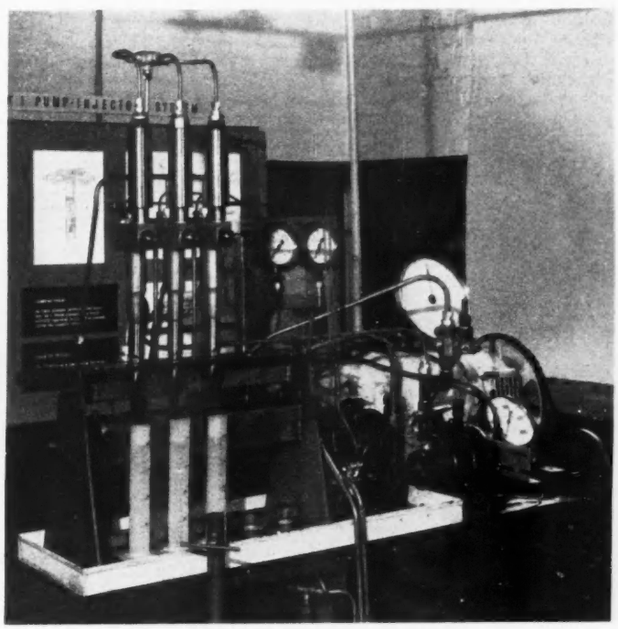
Problems of exhaust noise and the noise-radiating surfaces of an engine formed the subject of one exhibit which demonstrated the beneficial effect of changing the position of holding studs of a cast aluminium valve cover on the noise level, and also that a plastic cover showed no marked resonance and emitted very little sound.

Other methods developed towards the reduction of exhaust noise included the addition of projections to the exhaust valve to divide the gas flow at the valve seat into several streams, on the principle that discharge through a number of holes produces less noise than through a single hole of equivalent area. This device was found to reduce noise level by 12 dB mainly at the higher frequencies. A second method investigated involved the use of a simple capacity chamber in place of the usual manifold so as to reduce the amplitude of the pressure waves and it was found that by this means a reduction of 10 dB in the overall noise level could be obtained. The use of both devices at the same time resulted in a reduction of 22 dB.

Whether it is more efficient for fuel to be burned in a diesel engine before reaching or after impinging on a hot surface is being investigated and involves a study of the influence of metal temperature, air temperature and pressure. Towards this end a variable compression engine with an air inlet heater is being used, fitted with a "target," for the fuel spray, the temperature of which can be controlled and measured.

Pressure charging was the subject of several research items including a test rig to assess the advantages and limitations of various systems. That shown consisted of a turbo-charger, a B.I.C.E.R.A. compressor and an aftercooler in series, as applied to the smaller engines, a water spray being used for cooling. The problems set in the turbo-charging of high-speed engines are being studied under simulated turbo-charging conditions, with particular consideration being paid to the gas flow system and the velocity of inlet air. Present objectives are to attain a brake mean effective pressure of 200 lb per square inch, and a piston speed of 2000ft per minute. Work on high-pressure turbo-charging is also in progress on a larger engine, a Mirrlees Mark T.L.3 unit having a bore and stroke of 8¼in by 13½in being used. Two of the problems involved were overcome by fitting B.I.C.E.R.A. variable ratio pistons and hydraulically-operated fuel pumps. The incorporation of these developments has enabled the engine to operate without distress at a brake mean effective pressure of 290 lb per square inch at a mean piston speed of 1375ft per minute given a boost pressure of 22·7 lb per square inch gauge, a pressure considered to be quite feasible when the turbo-charging system is designed for the engine. Performance curves were shown: the current work is directed towards improving exhaust energy utilisation. Linked with the development of the high-pressure charging is the need for adequate factors of safety and to this end thermal conditions are being studied.

At present little is known about the inherent sources of damping in an engine and the effect of bearings in this respect has been investigated.



B.I.C.E.R.A. Mark 1 pump-injector system

In the experiments varying oil pressures and viscosities associated with various forces of excitation were used and the results indicated that the bearings had very little damping effect, so that attention is at present directed towards other factors, such as the detuning effect of pistons and connecting rods, which may limit the amplitude of torsional vibration. Flexible couplings having a low torsional stiffness can fulfil the function of modifying the natural frequency of a torsional system and so move the major criticals outside the speed range. In order to detune the system when a critical is approached couplings having variable stiffness have been designed, and on exhibition was one in which the stiffness varies as the square of the running speed. Thus, since natural frequency varies as the square root of stiffness, the natural frequency of the coupling is directly proportional to the speed. In tests with this coupling attempts to create a resonant condition failed to produce one-node vibration.

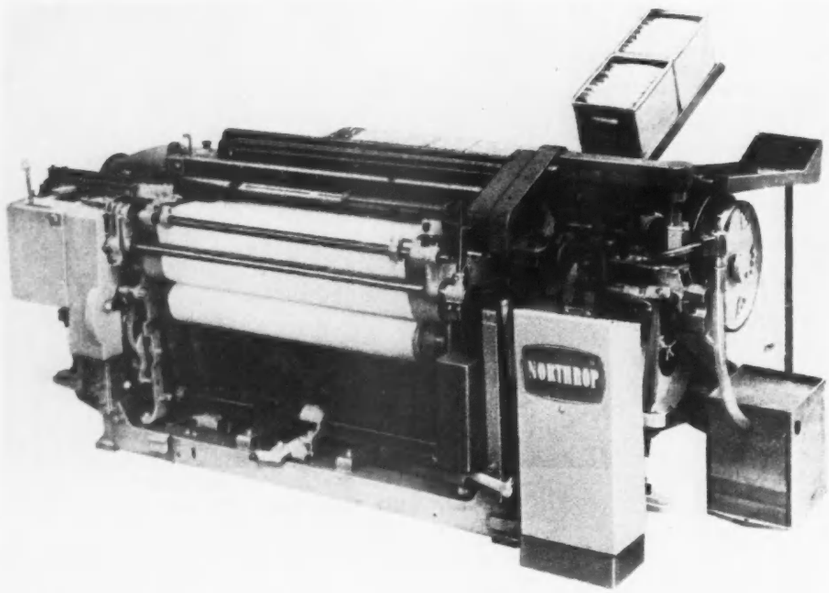
Of particular interest was the exhibit demonstrating the "Bicera" fuel injection system which has been evolved from the hydraulically-actuated but mechanically controlled fuel injection pumps already noted as being mounted on the T.L.3 engine. The system promises a saving in cost since it eliminates cams and followers and requires only simple pump plungers. Furthermore the design is compact since an 8mm plunger performs the same duty as a 20mm plunger in a mechanically operated pump and is housed within the injector body. Hydraulic operation makes for quietness, while the timing and rate of injection can be readily varied, and moreover there is a clean end of injection over the running range. In the system power is taken from the engine steadily and oil, which is

stored in an accumulator at 1000 lb per square inch, acts on a servo piston which in turn bears on a pump plunger so that the pressure is raised directly as the area ratio between piston and plunger. Timing control is by the distributor which controls the servo valve and thus the operation of the pump injector. With the valve in the feed position oil passes from the accumulator to the servo chamber and causes oil fuel to be injected, while with the valve in the metering position, oil at servo pressure bears on the lower end of the pump plunger and lifts the pumping assembly. The rate of lift is controlled by the throttle opening and period is controlled by the distributor, and these controls in conjunction vary the total lift and govern the output of the subsequent stroke. Our illustration is of the Mark 1 pump-injector system of which smaller editions have been developed in which the servo control valve has been eliminated so that only one pipe instead of three is required. It is understood that a unit fitted to a 3in bore engine has achieved 3000 injections per minute.

Looms and Loading Shovels

MANY examples can be cited of engineering firms which have diversified their manufactures to meet changing needs and circumstances. A somewhat unusual example of diversification has been effected recently in Blackburn, where looms for the textile industry and loading shovels for public works and building contractors are in production in the same factory. This has resulted from the merging of Chaseside Engineering Company, Ltd., of Hertford, manufacturers of the "Loadmaster" shovels, with British Northrop, Ltd., which has been making looms at Blackburn for many years.

During a recent visit to Blackburn, we were shown over the British Northrop factory which, with the foundry, covers an area of 1,100,000 square feet. The majority of the many components necessary in the assembly of the firm's high-speed automatic looms are produced in this factory. As there are several wooden components required, as well as pirns and bobbins by the thousand, the factory includes an extensive woodworking shop. At present, looms are being manufactured in widths from 20in to 210in. They are available for the weaving of cotton, worsted, wool, rayon and other synthetic fibres, and for jute and flax. The weft may be either one, two, three or four colours and there are models which incorporate motions for automatic weft feed, either by an automatic bobbin loader or by an attachment for pirn winding.



The Northrop "MRT" single shuttle, high-speed loom is equipped with an automatic bobbin loader

The "Loadmaster 1000" four-wheel drive loading shovel has a tractive force of 10,700 lb and a "pry-out" force of 13,800 lb. It is driven by a 61·5 b.h.p. diesel engine

A rotary weft and replenishing battery is the standard equipment on single-shuttle and two-box continuous weft mixing looms. On two- and four-box check looms, there is the alternative of a slotted vertical magazine or the rotary battery for two or four colours. A device which is now incorporated in these looms is a photo-cell feeler for detecting the exhaustion of weft during the flight of the shuttle as it is entering the box before the bobbin transfer. There is no physical contact between the feeler and the weft on the bobbin; the feeler operates with the electrical selection of the appropriate bobbin in the two- or four-colour battery or magazine.

An accompanying illustration shows an M.R.T. single-shuttle automatic topless loom fitted with a "GF" automatic bobbin loader. This machine is made in sizes for weaving fabrics from 40in to 90in wide and a continuous weft supply is maintained by the weft box (at the top of the loom) which holds seventy-two or 190 pirns. These pirns are moved by gravity from the box to a preparation and change position, the transfer of a pirn into the shuttle is then completed and the positioning of the next pirn to be changed is controlled pneumatically. The loose end of weft is stripped from the pirn and sucked into a nozzle and is clamped by a closing gripper plate. The sliding gearbox motion of the loom runs in a sealed oil bath and, to protect the gears, an escape motion is incorporated. In addition, the box motion is controlled by a separate pattern barrel which is synchronised with the dobby cylinder. There is also a safety escape on the box pedestal and a mechanism for stopping the loom if the boxes should lock. On single-shuttle narrow looms running at high speeds, a side weft fork is fitted which automatically stops the loom if the weft breaks. At such a stoppage, the shuttle will be in the right-hand box and the operation of a foot pedal enables the weaver to eject the shuttle in order to mend the broken weft.

Turning now to the other side of the business, that of Chaseside Engineering Company, Ltd., we saw in production at Blackburn the "Loadmaster 3000" and the "Loadmaster 1000" hydraulic shovels. The first of these machines, introduced about a year ago, has a payload of 10,000 lb, the maximum discharge height of the scoop being 10ft 2in. The engine is a 148 b.h.p. six-cylinder diesel and the power train employs a torque converter, automatic transmission and planetary hub reduction drive axles. The hydraulic system is supplied by a gear pump driven from the engine and there are four 7in diameter rams for operating the side arms of the scoop and imparting a crowding action. The nominal scoop capacity is 3 cubic yards, the maximum lift force is 20,000 lb and there is a maximum "pry-out" force of 22,500 lb. The machine has a top speed of 27 m.p.h.

The "Loadmaster 1000," which is the most recent Chaseside machine, is illustrated herewith. It is a four-wheel drive hydraulic loading shovel with power steering, powered by a four-cylinder, 61·5 b.h.p. diesel engine. The transmission incorporates a single-stage torque converter and hydraulic multi-disc clutches for forward and reverse with four speed ranges in both directions, maximum speed being 20·4 m.p.h. The nominal scoop capacity is 1½ cubic yards and the maximum discharge height, 9ft 6in. The maximum payload is 7000, and the angle of pry-out and discharge is 45 deg. The hydraulic system is supplied by a gear pump which gives 32·5 gallons a minute at an engine speed of 2250 r.p.m.

SHORTER REPORTS

Blackie and Son—150 Years Old

JUST over 150 years ago, to be precise on November 20, 1809, three young men came together in Glasgow and founded the publishing firm now known as Blackie and Son, Ltd. Their names were John Blackie, Archibald Fullarton and William Sommerville. Sommerville resigned from the partnership in 1821 and Fullarton left the firm in 1831. By that latter year, John Blackie's son, John Blackie junior, had joined the firm which took the title " Blackie and Son," which it still bears.

At a celebration party held at the Stationer's Hall in the City of London on November 20, an exhibition entitled " 150 Years of Publishing," was on view. It has been on view to the public all this week. In browsing over the exhibits we found them fascinating examples of the printer's and publisher's skill. How many people realise, we wondered, how excellent was some of the colour printing in Victorian days. Blackies have printed a rich variety of books during the 150 years of their existence ; but rather naturally we were especially interested in the more technical works. From its very early days the firm started to publish technical books. For example, *The Practical Measurer* and *The Mechanic's Calculator and Dictionary* figure in early lists. In 1843 there was published *The Engineer and Machinist's Assistant*, and in 1853 *Railway Machinery*. From there on the list seems endless. Notably it includes *The High Speed Internal Combustion Engine*, by Sir Harry Ricardo. Scientific books appear in the lists soon after the nineteenth century opened, for example, Prandtl's *Essentials of Fluid Dynamics* and Max Born's *Atomic Physics*. But more fascinating than all the others at the exhibition we found the children's books, many of which we recognised as favourites of our own many years ago !

We join with many other friends in wishing the firm of Blackie and Son good fortune in its publishing activities during the second half of its second century.

350MW Turbo-Alternators for Drakelow " C " Power Station

AT the invitation of the Central Electricity Generating Board, the English Electric Company, Ltd., Marconi House, Strand, W.C.2, is to start work on the design and construction of two 350MW steam turbo-alternators. They will be the largest turbo-alternators in Europe and the order, which is worth about £5,000,000, includes the associated feed-heating and evaporating plants. These sets will be installed in the C.E.G.B. Drakelow " C " power station, near Burton-on-Trent, which will have a total installed capacity of 1400MW to 1500MW.

The 350MW set marks a new stage in the development of the large single-shaft, single-alternator. It will consist of a three-cylinder 3000 r.p.m. reheat turbine with quadruple exhaust, arranged as a tandem compound unit taking steam from a John Thompson boiler and coupled to a direct cooled alternator.

In general arrangement the 350MW set is similar to the 275MW sets being built for the Blyth " B " power station of the C.E.G.B.

Steam is delivered at the turbine stopvalve at 2300 lb per square inch gauge, 1050 deg. Fah., and reheat steam returns from the boiler to the intermediate pressure cylinder at 1050 deg. Fah. The vacuum at maximum and economic rating is 28·7in Hg. (Bar 30in). To meet the specified high-pressure and temperature requirements, the high-pressure cylinder has a double casing over the first stages, the expanded steam being returned over the outside of the inner casing to pass through the remaining stages. With this arrangement the pressure differences and operating temperatures in the metal can be kept to values that allow established ferritic materials to be used in these casings, the stress levels being such as to keep creep deformation well within permissible limits. Castings are used for the steam chests and cylinder casings on the ground that they provide a more uniform thickness of material and corresponding thermal response, thus avoiding transient distortion associated with temperature changes.

The intermediate pressure cylinder has a partial double-casing construction similar to that of the h.p. cylinder. The quadruple-flow l.p. cylinder is arranged in two double-flow l.p. casings, each casing exhausting to one of the two condensers forming the twin condenser unit. The machines will be provided with proven automatic shaft gland sealing arrangements while improved electronic supervisory gear will be associated with centralised control to simplify operation, particularly in relation to speedy starting and running up to load.

The alternator has direct-cooled conductors, in a water-cooled stator winding and a hydrogen cooled rotor, the rated gas pressure being 45 lb per square inch gauge.

The feed heating system has seven bled steam stages comprising three surface type l.p. heaters, followed by a high-level direct contact storage de-aerator and by three h.p. surface type heaters. The feed system uses dual pumping, the three high-pressure heaters being interposed between the booster feed pump and the main boiler feed pump. The contract includes main boiler feed pumps either driven by separate auxiliary steam turbine or variable speed coupling from the main turbo-alternator shaft.

Electronics Laboratory Engineering Services

AT the invitation of Mullard, Ltd., Mullard House, Torrington Place, London, W.C.1, we visited on November 24 an exhibition of engineering technology arranged by the engineering division at the Mullard Research Laboratories, Salfords, Sussex. The exhibition had been organised by the division with the primary purpose of showing their colleagues in the research and design divisions some of the methods devised to meet special problems and to make intricate components before designs are released for production. The engineering division represents approximately one-third of the total strength at the laboratories and its facilities comprise an engineering laboratory, drawing-office and large model shops. Each engineer is a " design authority " on a particular subject and keeps himself abreast of all aspects of its development. The model shops employ instrument makers, tool makers, metal workers and staff engaged on wiring. All are highly skilled craftsmen, and those engaged on wiring collaborate in the planning of component layout.

Extensive use is made of etching techniques, and the exhibits included examples of its application to matrix cores, v.h.f. switch contacts and products such as front panels and name-plates. A special plant has been installed for the rapid production of printed circuits, using hydraulic mechanisms and other aids for passing the plates through the various processes without being touched by hand. Adhesives for bonding new materials are closely studied, and as an example, an item of airborne electronic equipment was shown in which " Araldite " had been used in building a structure capable of withstanding 15 *g* and temperatures approaching 100 deg. Cent.

A hydro-pneumatic tool has been developed in the division for accurate control in the zone refining of silicon. Speed of operation is infinitely variable from 1·5in per second to 0·001in per second by admitting air into the lower part of the control cylinder and regulating the flow of oil into the upper part by means of needle valves. The division also produces the carbon jigs used by girl operators for assembling transistors at the company's Southampton factory. Results obtained by employing special purpose machines such as the ultrasonic drill (originally developed in this laboratory) for producing complex shapes in hard materials were shown, and there was a comparative demonstration to illustrate the advantages of ultrasonic agitation for cleaning the surface of the metal and improving the adhesion of the solder in dip-soldering.

Associated Electrical Industries, Ltd., Reorganisation

ON January 1, 1960, the British Thomson-Houston Company, Metropolitan-Vickers Electrical Company and Siemens Edison-Swan, Ltd., will change their names to Associated Electrical Industries (Rugby), Ltd., Associated Electrical Industries (Manchester), Ltd., and Associated Electrical Industries (Woolwich), Ltd. respectively. At the same time five new Product Divisions of Associated Electrical Industries will officially come into being. They are as follows :

The Cable Division and the Construction Division which combine the interests of the S.E.S. Cables Division with those of W. T. Henley's Telegraph Works Company, Ltd., and Liverpool Electric Cables, Ltd.

The Telecommunications Division and the Radio and Electronic Components Division ; the former of these divisions has hitherto traded as a product division of Siemens Edison-Swan, Ltd.

All four of these divisions will be managed by Associated Electrical Industries (Woolwich), Ltd. (formerly S.E.S.).

The Instrumentation Division which will combine the interests of Sunvic Controls, Ltd., with the instrument and meter, X-ray, and Scientific apparatus departments of Metropolitan-Vickers and will be managed by Associated Electrical Industries (Manchester), Ltd. (formerly M-V.).

As from January 1, 1960, the total of A.E.I. product divisions to be established becomes twelve, and the famous companies whose names are to change will cease to trade, but will manage a number of A.E.I. product divisions. Their employees will be transferred to A.E.I. employment.

Birlec, Ltd., the heat-treatment and furnace manufacturing company, will be renamed A.E.I.–Birlec, Ltd., and will be managed by Associated Electrical Industries (Rugby), Ltd. (formerly B.T.H.).

Cable Eccentricity Control

AN addition to a range of components for cable eccentricity monitoring is announced by the Addison Electric Company, Ltd., 10–12, Bosworth Road, London, W.10. The various units in the range are designed on the building block principle and form a system of measurement depending on the comparison of the capacitances between the conductor or sheath of the cable and external self-aligning electrodes, using a radio-frequency bridge circuit. Measurement is made by gauge heads with spring-loaded electrode rods bearing against the cable, and the new unit in the series is a push-button selector switch enabling any one of four gauge heads to be monitored from one main instrument. The system has thus been extended to allow supervision of four different extension lines without transferring gauge heads from one to another, and is considerably more economical than the use of four complete monitoring systems.

[Reply Card No. E7055]

Traffic Studies and the Highbury Corner Intersection

ON Thursday, November 19, the newly-formed Traffic Engineering Study Group of the Institution of Civil Engineers held its first meeting. The meeting took the form of an informal discussion based on a brief paper entitled "Urban Intersections, with particular reference to the design of Highbury Corner." This paper, which was introduced by Mr. Joseph Rawlinson, Chief Engineer of the London County Council, gave the L.C.C's ideas on this subject, together with results achieved at Highbury. The following notes have been abstracted from the introductory paper.

An increase of about 50 to 60 per cent is a rough generalisation of the practicable extent to which the capacity of city streets may be increased. This increase of traffic is likely to be reached during the next decade unless some voluntary or artificial deterrent to traffic growth is applied. Generally, intersections have capacities appreciably below those of the streets leading to them, the roads as widened set a limit to which the intersection can usefully be improved. These considerations would normally set the justifiable reserve capacity for an intersection improvement at between 50 and 100 per cent, but a figure below this range would sometimes represent good value for money. Each intersection must be treated on its merits and any standard percentage increase in traffic would be quite unrealistic for design in congested urban areas.

Normal Signal Controlled Junctions.—Control by traffic signals has not had the same fluctuations in popularity as some other methods of improvement, but there has been a marked improvement in design technique. Coupled with the simplification of traffic movements, e.g., by re-routing right-hand turns, the idiosyncrasies of individual intersections can now generally be overcome. The resulting increase in efficiency has done much at comparatively little expense to mitigate the effects of the increasing traffic. A wider application of automatic variation in timing in step with fluctuations in volume of the various traffic stream will enable a further increase in efficiency to be realised at many of the more complex intersections. This country is well ahead in these techniques.

"*Channelisation.*"—This involves separating traffic cuts and dealing with them at a number of separate points usually controlled by linked two-phase signals. There are now few examples in this country of this method at complex, heavily loaded intersections, but much space is required and direction signs are complex. A five-way intersection generates twenty traffic streams of which sixteen cut one another fifty times. Although the actual number of separate cuts required can be reduced below fifty by running streams parallel as much as possible, full "channelisation" nevertheless becomes a very complicated business indeed, and in practice must be simplified by introducing a weaving element, by allowing more than one traffic cut at certain points, by prohibiting some of the less important traffic movements or by any combination of these devices. Even so, schemes are likely to have an unsatisfactory appearance and in the event of breakdown to be liable to serious stoppages.

Roundabouts.—A change has occurred during the last twenty years in expert as well as lay opinion of the value of roundabouts. Before the 1939–45 war many highway improvement plans included roundabouts for what now seem to have been inadequate reasons. Scientific assessments of their capabilities had been undertaken on a limited scale, and knowledge was limited to a few recommended typical designs, usually symmetrical, and a few rules, e.g., as to the relation between weaving length and carriageway width. Opinion has now veered so much that it is considered by some almost reactionary to suggest a roundabout unless it can be described as a useful adjunct to a flyover or underpass scheme. This is to be deplored because present disfavour is largely due to poor geometric design and inadequate size (so as to limit property disturbance). It is also true that many were put in to cater for some rather hypothetical future need.

Although the roundabout has limitations it is sometimes superior to any other form of design, except possibly grade separation, and lends itself better to good amenity treatment.

Grade Separation.—While the value of grade separation in reducing delay and accidents with fast moving traffic has long been recognised its value in augmenting capacity at city intersections has been less apparent. An increasing number of intersections in London can only be given an adequate reserve capacity by incorporating a flyover or underpass, and at some of the more complex junctions three-way flyovers or improvements at three levels have been seriously considered recently. A simple flyover or underpass deals with part of the problem only and the turning traffic must be dealt with at ground level.

HIGHBURY CORNER, ISLINGTON

The recent improvement at Highbury Corner has been selected as an illustration because it is a fairly typical urban intersection and not because of unusual features.

Before improvement this intersection was controlled by vehicle actuated signals of modern design operating in three phases with an additional pedestrian phase brought in by push-button. Filters were provided for all left-turning traffic. The maximum cycle time was about ninety seconds. The secondary junction of Canonbury Road with St. Paul's Road was not controlled by signals.

A traffic count taken in 1948 showed that an average of 1200 vehicles per hour passed through the intersection, and that at peak times this increased to about 1500 vehicles per hour. There was also an appreciable pedestrian movement across the roads at the main junction. By 1957 the traffic flows had increased by about a third and congestion had mounted so much that the police operated the signals for several hours each day. Observations over a period of several weeks showed that the delay amounted to just under 200 vehicle hours lost per twelve-hour day, with the delay at the morning peak period running at about three times this rate. The economic loss to the community of the delay was estimated to be about £70,000 per annum.

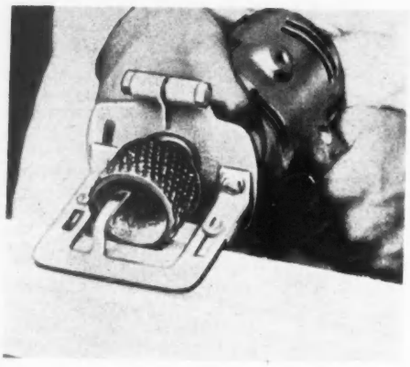
A roundabout solution was therefore adopted. Work began towards the end of 1957 and was completed in 1958. Using traffic volumes and distribution during the morning and evening peak hours soon after the scheme was completed and the Road Research Laboratory formula for weaving sections, it is estimated that the scheme now has a reserve capacity of about 70 per cent. This will not, however, be achieved until the trolley buses are removed and better facilities provided for pedestrians to cross Holloway Road. Delays at the intersection have now been reduced to those caused by the interruptions of flow at the uncontrolled pedestrian crossing at Holloway Road, and the extra time taken by some traffic stream to cover longer distances. If and when the widening of Holloway Road is eventually achieved it may be possible to incorporate a pedestrian subway.

The scheme so far has been highly successful. Its total cost was about £88,000 which, having regard to the previous economic loss to the community of £70,000 per annum on account of delays, means that it has paid for itself in under eighteen months.

Cutter Drum Attachment for Power Tools

A NEW attachment for power tools in the "Surform" range of tools made by Simmonds Accessories, Ltd., Stornoway House, St. James's, London, S.W.1, is the cutter drum shown in use in our illustration. This 2in diameter cutter drum comprises essentially a cylindrical arrangement of the well-known "Surform" blade as used in the firm's files and planes. When fitted on a power drill it can be used for free-hand forming in a similar manner to a sanding disc except that the cutting edge is on the side of the tool instead of on the face, only a little pressure being required to impart a smooth surface. For rebating work the power tool can be fitted in a drill stand or bench clamp. Whilst the tool is cutting the chips pass through the holes in the blade and are automatically cleared from the centre of the drum.

A useful universal planing and rebating attachment provided for free-hand use with the cutter is shown fitted to the drill in our illustration. By adjustment of the graduated slotted slides in this attachment rebates up to $\frac{5}{8}$in square can be cut quickly and accurately. When it is required to use the drum for planing purposes the slide plate controlling width is removed and that controlling depth set to its shallowest level to act as a guide which ensures that the drum operates smoothly and evenly. In the course of a recent demonstration we were shown that the new cutter drum can be used effectively after working with it for only two or three minutes.

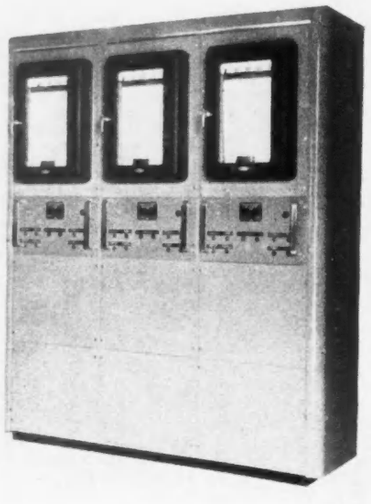


Cutter drum attachment for adapting power tools for planing, shaping, bevelling and rebating woods. This tool can be used free-hand, with a drill stand or a bench clamp, or in conjunction with the planing and rebating attachment as shown

[Reply Card No. E7062]

Impregnation Monitoring

A NEW range of impregnation monitors for supervision of the vacuum impregnation of electrical products has been introduced by the Addison Electric Company, Ltd., 10/12, Bosworth Road, London, W.10. A potentiometer recorder has replaced the galvanometric instrument fitted previously, and is of a larger size, giving greater ease of observation. Selector switches enabling up to three tanks to be monitored by each if desired and various other facilities to be brought into action, are now incorporated in the monitor cabinets. The four quantities measured and recorded by the equipment are insulation resistance, capacitance, temperature and vacuum.



Control station for monitoring three impregnation tanks for cables, transformers and capacitors

A new feature of the present series of monitors is a range switch for extending the resistance measuring range ten times. Basically the monitor is a single unit in a self-contained grey cabinet for floor mounting, but any number can be combined to form multiple control stations. We understand that the recorders are being used increasingly in the manufacture of capacitors and transformers, and our illustration shows a three-unit recording station for monitoring the vacuum impregnation process in three tanks, treating cables, transformers and capacitors.

[Reply Card No. E7063]

Extending TV and Radio Coverage

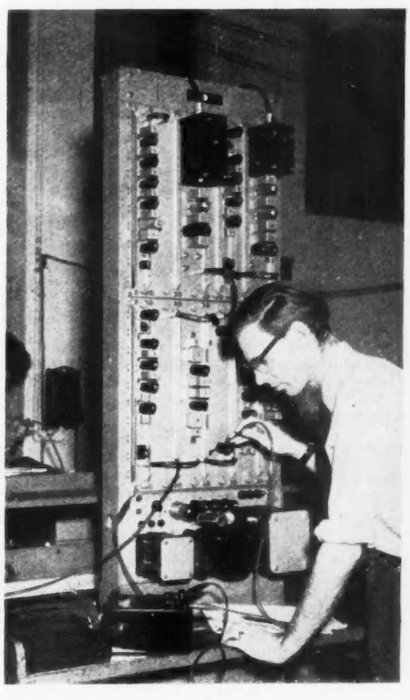
IN areas where topographical conditions cause the field strength of television or v.h.f. sound transmissions to be insufficient for normal domestic receivers, service can be provided by setting up local equipment to relay the signals from the distant stations on a different frequency. The apparatus shown under test in our illustration is a Marconi television translator for "gap-filling" by this method. The British Broadcasting Corporation recently placed a contract with Marconi's Wireless Telegraph Company, Ltd., Chelmsford, Essex, to the approximate value of £115,000 for the supply of television and v.h.f. sound translators, low-power television transmitters and amplifiers to extend the coverage of the corporation's vision and sound services to areas where at present reception is non-existent or unsatisfactory.

In addition to receiving broadcast signals and retransmitting them, the BD368B equipment illustrated will accept and transmit locally-produced programmes by a simple switching operation. As another alternative the apparatus can be supplied as a low-power transmitter only. All these functions are required in the present programme. The translators will be installed in duplicate, mounted side by side in two racks, with the addition of an automatic changeover panel.

Radio signals received at the translator are fed to the receiver r.f. unit through bandpass filters designed to allow operation at a minimum of one-channel separation between received and retransmitted signals. The r.f. unit consists of a double-triode valve in a cascade input stage followed by a triode mixer, where the signal is mixed with the output of a heterodyne oscillator comprising a crystal-controlled oscillator, buffer and multiplier stages. For 405-line (5 Mc/s channel) working the resultant intermediate frequencies are 34·65 Mc/s (vision) and 38·15 Mc/s (sound). The signals are then separated and amplified at i.f. before mixing with the output of a second heterodyne oscillator which changes the frequencies to the desired output channels. Further stages of linear amplification follow the mixers of the sound and vision channels. Power output on vision is 10W peaks. Amplifiers may be added to bring the peak vision power to 100W or 500W.

The vision and sound transmitter stages for dealing with signals received by landline consist of the necessary oscillator, multiplier and modulator stages for feeding sound and vision signals at the appropriate frequencies into the i.f. amplifiers mentioned above. Equipment ordered by the B.B.C. includes ten 10W television translators, four 10W television transmitters, and thirty frequency-modulated translators to perform similar functions for the corporation's v.h.f. sound service.

[Reply Card No. E7071]



The television translator seen above under test at the maker's works contains the circuits required for receiving, frequency-changing and rebroadcasting sound and vision signals from main transmitters and for operating as an independent low-power transmitter

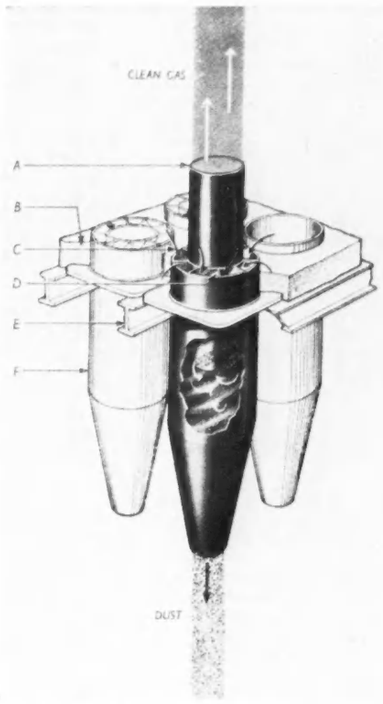
Multi-Cell Cyclone Dust Collectors

A MULTI-CELL cyclone dust collector known as the Holmes-Rothemule reverse-flow "UK" is now made by W. C. Holmes and Co., Ltd., Huddersfield, for applications where good gas distribution conditions cannot economically be achieved and large gas volumes are encountered. The general construction and principle of operation of these collectors can be seen from the diagram we reproduce.

Each collector comprises an assembly of cyclone cells, the number of which is directly proportional to the volume of gas to be cleaned. Each cyclone cell is an assembly of two concentric tubes, forming an outer dirty gas cylinder with a stationary impeller fixed at the upper inlet end and an inner clean gas tube which passes up through the centre of the impeller. The outer cylinder is about 10in diameter and its lower part tapers down to a conical shape.

A grid through which the individual cells are supported is enclosed in a rectangular casing the lower half of which provides a dust bunker. The upper ends of the clean gas tubes terminate in a stepped floor in the top part of the casing and the assembly is such that individual cells can be readily removed for inspection and maintenance purposes. A special sealing compound is used to make gastight joints between the cells and their supporting grid to ensure that dirty gas does not by-pass the cells.

In operation the impeller imparts an intense swirl to dust-laden gas as it enters a cell causing the gas to descend with a spiral motion. Near the apex of the conical section of the dirty gas cylinder the axial velocity of the spiralling gas is turned through 180 deg. This reversal of direction causes the dust to be centrifuged and it is propelled downwards into the dust bunker whilst the dust-free gas passes up through the clean gas tube to the exhaust fan and stack. The high separating efficiency of the collector is derived from the relatively small diameter of the individual cyclone cells.



A—Clean gas tube.
B—Sealing compound.
C—Dirty gas entering cell.
D—Stationary impeller (cast iron).
E—Supporting grid.
F—Outer cylinder (cast iron).

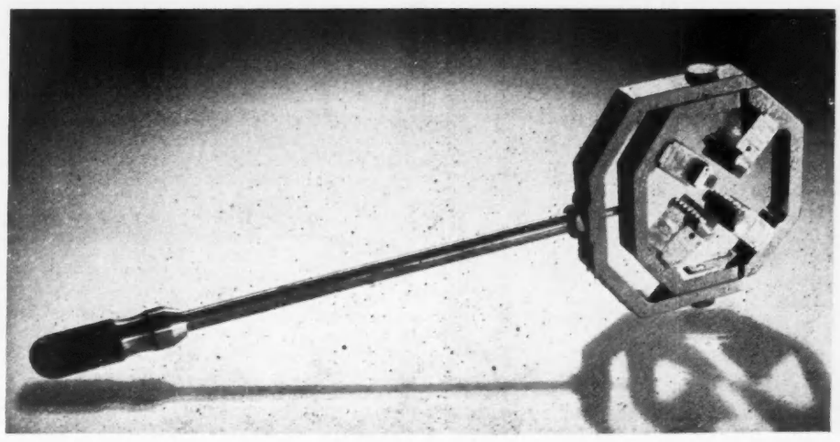
Construction of reverse flow, multi-cell cyclone dust collector

The efficiency of these collectors depends naturally upon several factors including particle size and density of dust. Curves plotted by the makers for dust densities of 2 grammes per cubic centimetre show that collectors have an efficiency of about 81 per cent for particles up to 10 microns rising to 98 per cent for particles of 40 microns and upwards.

[Reply Card No. E7072]

Honing Tool for Shafts

WE illustrate a new lathe tool for honing and superfinishing straight or cranked shafts which has been introduced by Nicol and Andrew, Ltd., Hillington, Glasgow, S.W.2. This tool consists of a split head carrying four abrasive stones in shoes and clamped round the workpiece



Hand-controlled lathe tool for honing shafts

on the lathe. A central spindle passing through the main support rod provides a hand screw adjustment for the control of abrasive stone pressure on the workpiece.

When mounted on a machine the main support rod of the tool passes through a sleeve which is pivoted on a secondary rod working within a sleeve block located in the lathe toolpost. With this form of mounting the hone will then automatically follow the "throw" of a cranked shaft revolving in the lathe while still under pressure control by the operator. The secondary rod being held firmly in the sleeve block allows lateral stroking movements on the workpiece. It is stated that the lathe hone is available in four models covering shaft diameters from 2in to 12in, and the size of the lathe bed is the only limit to the length of shafts which can be honed and superfinished.

[Reply Card No. E7073]

Copying, Routing and Milling Machine

A HAND-OPERATED machine designed to cover a wide range of copying, profiling, routing and milling operations, which is now made by Taylor, Taylor and Hobson, Ltd., Leicester, can be used for the direct two-dimensional 1 to 1 reproduction of workpieces up to 8½in by 14in with an overall height up to 8½in. It is suitable for operation by semi-skilled or unskilled labour and the general construction of the machine can be seen in the photograph reproduced below.

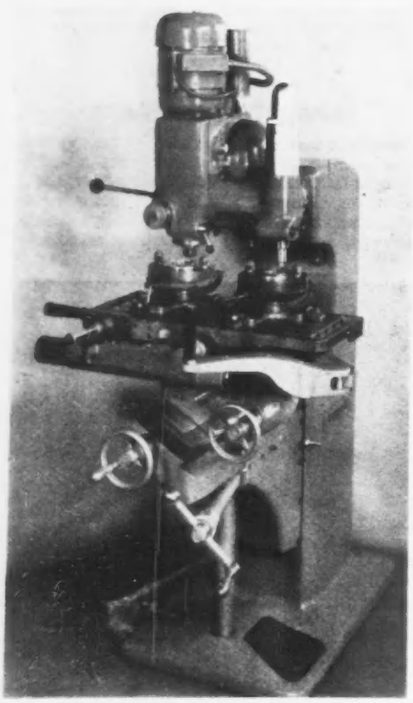
The head unit is mounted on a deeply throated column on which it can be swivelled up to 45 deg. on each side, 30 deg. forwards or 60 deg. rearwards for milling operations. This head incorporates the cutter spindle complete with its drive and has detachably mounted on its side a tracer unit. The cutter spindle drive is transmitted from the motor by paired belts on pulleys giving a range of spindle speeds from 500 to 18,000 r.p.m. A brake acting directly on the motor pulley is operated by a push button at the front of the head. Parallel shank cutters up to ¾in diameter or taper shank engraving cutters can be fitted in the spindle. The cutter spindle has means of lever-operated coarse feed or a fine feed through worm reduction gearing with reference to a ring graduated in 0·002in steps.

The tracer attachment spindle, following normal practice, is designed to take a tracer rod of similar diameter to the cutter in use when copying. This tracer spindle, set at a centre axis distance of 9in from the cutter spindle, is directly coupled to the cutter spindle feed mechanism so that the tracer rod is moved vertically in conjunction with the cutter. For setting purposes a tracer spindle vertical adjustment of 2½in is provided.

The knee of the machine has a vertical adjustment of 12in on the column and it carries the main table on inclined slideways. This 20in by 10in table has hand-operated longitudinal and cross traverses of 12in. When the machine is used for two-dimensional copying work a duplicator table is mounted on the work table to carry both the workpiece and the master component or pattern as shown in the illustration.

The 20in by 10in duplicator table is carried on ball bushings running in slide bars to make possible a free, almost effortless longitudinal and transverse movement by manual operation. It is moved over an area of 4in by 3in by a handle on the right hand which through a pantograph gives a 3 to 1 mechanical advantage. During copying the degree of manual control is supplemented by the operator grasping a second handle at the left hand end of the table. The 4in by 3in work area covered by this floating manual control is increased by increments as work proceeds by longitudinal and transverse adjustments of the main table to cover work areas up to a maximum of 8½in by 14in. When using the duplicator table work up to 8½in high can be accommodated below the cutter.

[Reply Card No. E7081]



Machine fitted with duplicator table and arranged for two-dimensional copying

Rapid Testing for Radioactivity

A VERY rapid method of testing for weak radioactive contamination, such as might be found on the hands of personnel working with radioactive materials, has been devised in the electronics division of the United Kingdom Atomic Energy Research Establishment at Harwell.

The invention is based on the observation that, although the random nature of individual radioactive disintegrations requires that very many may be counted if a statistically reliable measurement of radioactivity is needed, in cases where it is only required to find out whether or not the activity exceeds a set level, it is—in principle—only necessary to carry out a long count when the activity is close to this level. Sources which are much stronger or much weaker can—in principle—be disposed of by making a far less accurate measurement in a much shorter time. This result can be achieved by applying the principle of sequential sampling, a technique used in production control. The method is to count the number of radioactive disintegrations observed since the beginning of the counting period and to subtract continuously the number which would have been observed had the activity been exactly equal to the set level. The difference between these two numbers grows continuously and when it has attained a predetermined value (positive or negative) the test is ended. The sign of the difference then shows whether the activity is greater or less than the set level. The more the activity differs from the set level the faster this difference is accumulated and the shorter is the time taken to complete the test.

The electronic instrument which performs this function is called a difference integrator. It may take several forms. In one, each pulse due to a disintegration causes the charge on a capacitor to be increased by a known amount. At the same time charge is being continuously withdrawn from the capacitor at a rate corresponding to the set level of activity. When the net charge on the capacitor reaches a predetermined positive or negative value, a "high" or "low" indicator operates and the test is ended. Another version uses a reversible pulse-counting device driven in one direction by the unknown pulses and in the other by pulses from a standard pulse source.

The method has been studied experimentally and on a digital computer. It is found that, although a few sources whose activity is very close to the set level may cause very long counting periods, there are several simple ways in which these periods may be curtailed without appreciably affecting accuracy.

The advantage to be obtained by use of the above method, rather than conventional methods, depends on the expected distribution of activities between samples and on the accuracy required. In the case of routine monitoring of activity on the hands, a five-fold reduction in average counting time is obtained without loss of accuracy. In another case, the mean time for the routine measurement of a weak radioactive sample is reduced from eight hours to twenty minutes, again without loss of accuracy.

[Reply Card No. E7082]

Engineering Display at Islington

MEMBERS of the North London Group of the Engineering Industries Association held a display of their products at Islington Town Hall on November 17. These were selected to a large extent from items of wide general application, and a feature was the variety of variable speed drives on show. Two hydraulic units were exhibited by Vacuum Research (Cambridge), Ltd., Quayside Bridge Street, Cambridge. These comprise a hydraulic pump driven at constant speed by electric motors of from 0·5 h.p. to 2 h.p., and a hydraulic motor connected to the output shaft. An infinitely variable range of output speeds is obtained by means of a hydraulic servo-mechanism which varies the inclination of the cylinder block of the input pump, thus determining the volume and direction of the oil flow delivered to the output motor. Both machines may be combined in one unit or separated. A "Mecontrol" electronic control in a cabinet measuring 15in by 9in by 9in was demonstrated by The Medical Engineering Company, Ltd., 4, Fountayne Road, Tottenham, London, N.15, together with a range of fractional horsepower motors built to suit the circuit characteristics. The control unit incorporates a thyratron with feedback to its grid circuit dependent on the motor back e.m.f. so that the selected motor speed is held constant against varying load. Claude Lyons, Ltd., Valley Works, Hoddesdon, Herts, showed motor speed controls incorporating "Variac" variable auto-transformers and selenium rectifiers. One of these enables individual forward and reverse speeds to be preset and selected by the reversing switch. Motors between $^1/_{15}$ h.p. and 1½ h.p. may be controlled. A miniature automatic tap-changer to compensate for mains voltage changes and so improve the life and stability of valves and other electronic components was shown by the same firm. An electronic sensor unit compares a rectified sample of the mains voltage with a stable reference voltage and operates micro-switches connected to the transformer tappings when input fluctuations occur, maintaining an output voltage within ±5 per cent of the declared value for input charges between −20 per cent and + 10 per cent.

Among the electronic instruments at the exhibition was a new signal generator, model 1450, just introduced by Cossor Instruments, Ltd., Cossor House, Highbury Grove, London, N.5. The generator is directly calibrated in frequencies and covers from 150 kc/s to 390 Mc/s in seven ranges, giving a c.w. output which may be amplitude-modulated by the internal oscillator or from an external source.

Narrows Bridge, Perth

IN our description of the Narrows Bridge at Perth in Western Australia published on pages 648 and 655 of THE ENGINEER last week, acknowledgment was not given to the firms responsible for the design and construction of the bridge. The bridge was built for the Commission of Main Roads of Western Australia, and is of British design. The consulting engineers responsible for the bridge were Messrs. G. A. Maunsell and Partners, and the design consultant for the deck structure was Mr. E. W. H. Gifford. The consulting architects were William Holford and Partners. The general contractor was Christiani and Nielsen of Copenhagen, in association with J. O. Clough and Son (Pty.), Ltd. The bridge was opened by the Governor of Western Australia, Sir Charles Gairdner, on November 13.

Reflecting Telescope for Japan

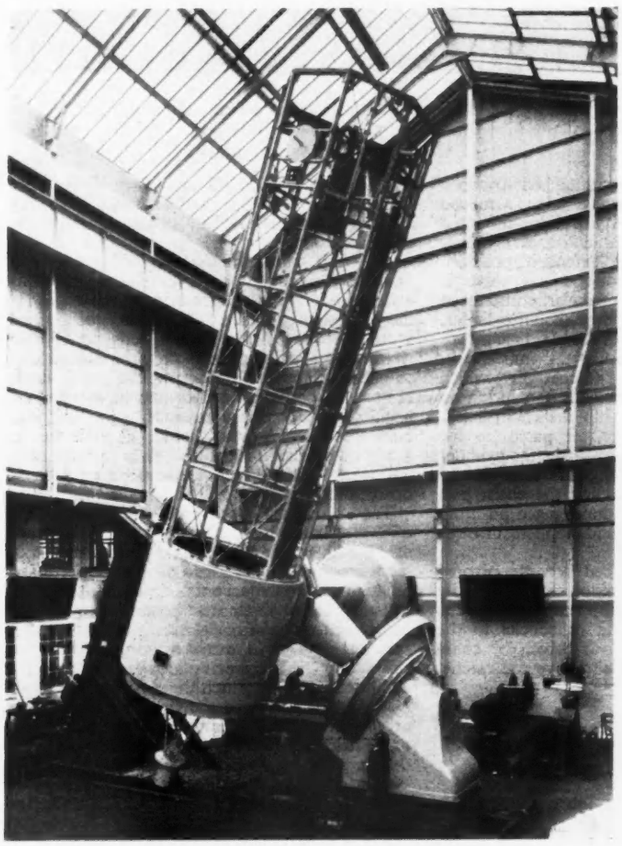
FINAL tests of a 74in reflecting telescope for the Okayama Astrophysical Observatory, Japan, have been completed at the works of Sir Howard Grubb Parsons and Co., Ltd., Newcastle upon Tyne, from whom the telescope was ordered in 1955. Despatch will take place early next year, four months before the original delivery promise. The observatory is a new one, and will be a branch of the Tokyo Astronomical Observatory. The telescope, seen undergoing tests in our illustration, is to be erected at the top of Mount Chikurin (1200ft) near Karragota in the Okayama prefecture, about 500 miles south-west of Tokyo. It will be the largest telescope in Asia.

The main optical component of the telescope is the parabolic mirror, consisting of a disc of low expansion glass 74in in diameter and about 11in thick with its front surface ground and polished to a concave parabolic form accurate all over to about two millionths of an inch. This piece of glass weighs more than 1½ tons. The surface was ground and polished in the optical department of Sir Howard Grubb Parsons and Co., Ltd., as also were the five smaller subsidiary mirrors.

The mounting and mechanisms required to move it were all designed and made by the same firm, and the 50 tons of moving parts can be directed to any desired part of the heavens by means of electrical control systems operated by push-buttons. Some idea of the precision of an instrument of this kind can be gained from the fact that a star image formed on the photographic plate will be no more than one thousandth of an inch in diameter, and this image produced by reflection in the large mirror, must be held steady on the plate to less than a thousandth of an inch. To do this the whole telescope must be pointed at the moving star with an accuracy of less than a second of arc for some hours (equivalent to a pointing accuracy of the diameter of an orange 20 miles away).

For transport to Japan, the telescope will be dismantled into some six or seven major sections and packed in forty-seven crates of various sizes up to 23ft by 9ft by 9ft. Its re-erection on site will be supervised by engineers from the maker's works. Sir Howard Grubb Parsons and Co., Ltd., states that when this work is completed the firm will have installed 74in reflecting telescopes on all five continents.

[Reply Card No. E7091]



The 74in reflecting telescope for Okayama astrophysical observatory undergoing tests in the maker's works

Railway Accidents in 1958

THE annual report of railway accidents presented by the chief inspecting officer for railways to the Minister of Transport and Civil Aviation shows that the total number of persons killed in the working of the railways during 1958 was 217 (351 in 1957) and 24,031 were injured (24,514 in 1957). In the 1186 train accidents reported thirty-six people were killed and 1169 injured; of those killed, eighteen were passengers, five railway servants and thirteen other persons. In movement accidents thirty-three were killed and 4858 persons were injured, a majority as a result of misadventure or carelessness. Non-movement accidents caused the death of eleven and injury to 16,006 people.

The report draws particular attention to a marked decrease in casualties to railway servants which is considered to be due primarily to the staff having become more safety-conscious. This marked reduction is, however, stated to be no reason for complacency, as most of the accidents which did occur were the result of individual carelessness, and 70 per cent of the movement fatalities occurred when men were at work on the permanent way where conditions are known to be hazardous.

Although an increase was noted in the number of derailments as a result of defective track or signal apparatus particular emphasis of this fact is not given in the report, because these numbers tend to fluctuate from year to year. Post-war records have shown that there has been a steady decline in these types of accidents and the trend in this direction is considered to be more important than isolated figures for a particular year.

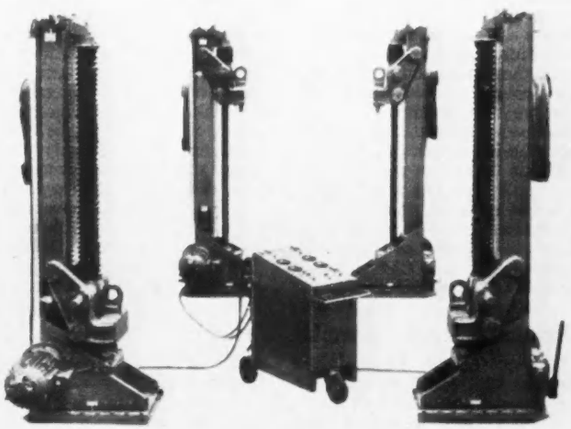
Identification of Chromium-Plated Finishes

IN conjunction with the issue of British Standard 1224 : 1959 "Electroplated Coatings of Nickel and Chromium," see page 679, a labelling scheme has been devised by the Mond Nickel Company, Ltd. That firm, working in collaboration with the British Standards Institution, will supply labels to platers and manufacturers of plated products which undertake to apply the labels only to plating which complies with B.S.1224. The new standard calls for three grades of plating depending on the use to which plated products are put. The Mond labels take this into account. They will be coloured red (which indicates suitability for "severe" service), blue ("normal" service), or green ("mild" service). Plating which is to be exposed for long periods in the open should have a red label; that used indoors but where corrosion is likely (in steamy kitchens and bathrooms, for example, or on products stored in damp cupboards) should bear a blue label. Where less arduous conditions are involved the green-for-mild category will be quite sufficient. Each of the labels will announce that the nickel-chromium plate conforms to British Standard 1224 : 1959. At this stage, it will be left to platers and manufacturers to satisfy themselves that their finishes are in accordance with the standard.

[Reply Card No. E7093]

Heavy Duty Screw Jacks

WE illustrate a group of 20-ton capacity motor-driven screw jacks made by Matterson, Ltd., Shawclough, Rochdale, typical of the units supplied by the firm to British Railways for locomotive servicing at the Longsight depot, Manchester. This new design of jack is designed to raise a weight of 20 tons on a projecting pad to a height of just over 7ft from a minimum height of 2ft 3in above floor level. In each jack a 3 h.p. flange-mounted squirrel-cage motor drives a worm and spur reduction gearing which turns the lifting screw to give the load pad an elevating speed of 6in a minute. Through the pad bracket assembly the reaction of the overhung load is transmitted by rollers with needle roller bearings on to renewable hardened steel strips on the box section jack columns.

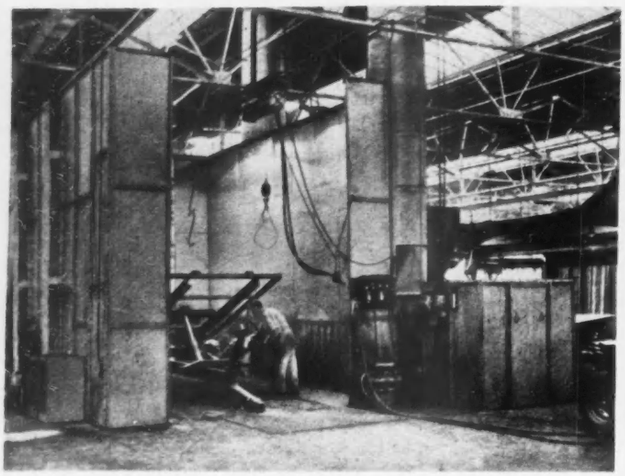


Group of motor-driven 20-ton screw jacks with central control console

Normally these jacks are used in groups of two, three or four; and for ease of control they are connected by trailing wires to a portable console type contactor box and control desk. From this desk each jack is controlled by a numbered switch selecting an individual contactor; a master switch being used to energise the selected contactors simultaneously and operate the jacks upwards or downwards.

Ammeters in each circuit indicate load distribution among jacks, and give advance warning of possible overload, the usual electrical overload protection being provided. Electrical limit switches cut out the operation of all connected jacks whenever a single jack reaches its upper limit of travel, but other jacks can be moved upwards after the one at its upper limit has been switched off. Other jacks of this design are made in 16-ton and 25-ton capacities by the firm.

[Reply Card No. E7094]



Water-wash paint spray booth in which the conventional circulating water pump equipment has been dispensed with

Rotary indexing machine dispensing components for printed circuits at a radio factory

Paint Spray Booth

THE conventional water circulating system using pumps, spray nozzles and filters has been dispensed with in the "Nopump" down-draught paint water-wash spray booth equipment developed by Alfred Bullows and Sons, Ltd., Long Street, Walsall, Staffs. A typical booth of this design, which we illustrate, has a working area 22ft 6in long by 13ft 6in wide.

With this system the contaminated air drawn from the booth in the form of a high velocity stream passes across the surface of a tank and entrains a large amount of water. This stream of air-laden water, still at a high velocity, is carried through a number of changes of direction in the course of which the heavier particles of paint are thrown outwards into a water tank. In subsequently contacting a series of eliminator plates the finer particles of paint and the water in the air stream are deposited on the plates to drain down into the water tank. The cleaned air is then exhausted to atmosphere.

The paint collected in the tank forms a silt which needs to be cleaned out only at lengthy intervals.

[Reply Card No. E7101]

Printed Circuit Assembly Device

TWENTY rotary storage and dispensing machines known as "Rotasemblers," developed and manufactured by Work Study Equipments, 4, Montalt Road, Woodford Green, Essex, are in operation at the Romford factory of Regentone Radio and Television, Ltd. These rotary indexing machines store and dispense small electrical components such as resistors and capacitors for assembly on printed circuit boards for radio and television receivers. The indexing mechanism is operated by compressed air through "Maxam" pneumatic control equipment manufactured by Maxam Power, Ltd.

In the form illustrated, the "Rotasembler" is 28in in circumference and 26in high and is capable of storing up to thirty-eight different components in nineteen vertically-divided hopper units. Single-compartment hoppers to other dimensions can be provided if required. In the double-compartment type shown, the feed lip of the outside hopper is located above that of the inside hopper and both are fitted with an adjustable gate which controls the flow of components to the feed lips. The dividing plate between the hoppers protrudes above the level of the double-hopper unit to facilitate filling.

The complete "Rotasembler" is carried on a Y-shape mounting plate which is bolted to the assembly area at three points. A rigid support shaft at the centre of the Y-plate carries a hollow drive shaft with the indexing mechanism at its lower end. The indexing mechanism comprises a ratchet gearwheel and a fixed gearwheel attached to the drive shaft. The ratchet gear is driven by a short chain which is attached at one end to the centre of a pivoted lever and at the other end to a spring attached to a peg on the Y-plate. The pivoted lever is moved by the piston of a "Maxam" trunnion-mounted 1¼in bore, 2in stroke, double-acting air cylinder which is normally in the extended position. When the "Maxam" foot-operated valve is depressed by the assembly operator, compressed air passes to the forward end of the air cylinder, causing the piston to retract, which in turn moves the lever and chain. During this movement, the chain is drawn past the ratchet gear, which is in the disengaged position, and the spring on the end of the chain takes up the chain slack. On releasing the foot valve, air passes to the other end of the cylinder and forces the cylinder piston outward, thus moving the lever in the opposite direction and drawing the chain past the gear which is now in the engaged position, and turns the drive shaft and hoppers through approximately 19 deg.

A braking system controlled from the pivoted lever is brought into operation simultaneously with the movement of the hoppers and stops the rotation without over-riding or shocks to the machine. The brake shaft is driven by chain from the fixed gear mounted above the ratchet gear on the drive shaft.

[Reply Card No. E7102]

Heavy Duty Spinning Lathe

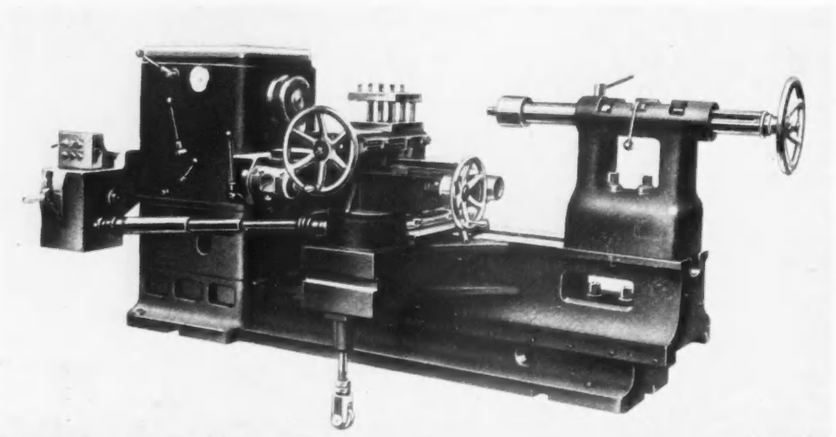
THE 36in spinning lathe illustrated on this page has been developed by Charles Taylor (Birmingham), Ltd., Bartholomew Street, Birmingham 5, for heavy duty work. The machine has a centre height of 22½in above the sliding bed with a 13½in deep gap 33½in wide. The maximum distance between the spindle face and the back centre is 56in and the sliding bed, with a travel of 25½in, carries a tool slide having a longitudinal travel of 23½in and a transverse travel of 10in.

A 7½ h.p. motor at the rear of the machine drives a Churchill-Sturm hydraulic motor from which the drive is transmitted by vee ropes to the headstock spindle. This arrangement gives a stepless range of spindle speeds up to 900 r.p.m. and enables the spindle to be started and stopped without need for switching the main motor. A combined wheel and lever-operated back-centre gives rapid advance to the spinning blank, and a revolving holder is mounted in heavy duty roller and ball bearings to withstand the axial and thrust loads during spinning operations.

The sliding bed is moved along the main bed of the machine by a 2 h.p. motor-driven lead-screw and, in addition to providing a means of increasing the gap width to enable blanks up to 6ft diameter to be accommodated, this mechanical adjustment facilitates speedy setting of the compound rest and back centre in new working positions. A rigid extension on the front of this sliding bed supports the rotary base of the compound rest by which the revolving slide can be adjusted relative to the work. A drive from a gearbox at the left-hand end of the lathe gives ten rates of toolslide feed from 0·0078in to 0·18in per spindle revolution.

Depending from the front of the extension on which the compound rest is mounted is a support leg which is adjustable for height. A roller at the foot of this leg can be mounted on the track of a suitable rail to give additional support to the slide when heavy gauge material is being spun on a machine.

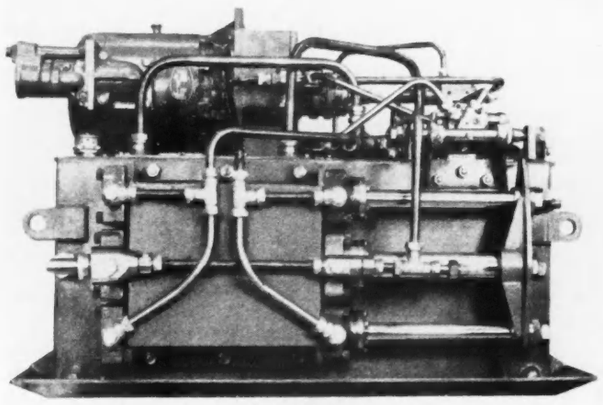
[Reply Card No. E7103]



36in mechanical spinning lathe

Hydraulic Pump Set for Mines

A HYDRAULICALLY-DRIVEN direct-acting pumping equipment is now made by Richard Sutcliffe, Ltd., Wakefield, for underground applications in mines such as the supply of water under pressure for the operation of the ramming gear of armoured chain face conveyors. As can be seen in the illustration, each equipment is of self-contained "power pack" construction, and they are designed to pump mine water to which there is added soluble oil to minimise corrosion.



Pump for mining applications where water is required at high pressure

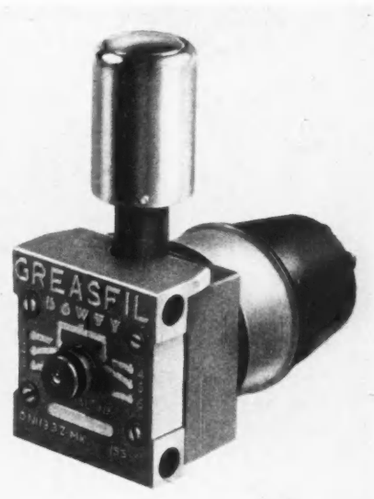
The complete equipment is built on a galvanised tank holding 100 gallons of treated oil, and a 7½ h.p. motor-driven hydraulic pump and valve gear are mounted on the top of the tank. This hydraulic pump supplies the pressure fluid to two double-acting cylinders on the side of the tank. The water pumping cylinder is mounted between the hydraulic cylinders on the side of the tank and its piston rod is coupled to the rods of the hydraulic cylinders by a yoke. The designed capacity of the set is 5 gallons per minute at 1000 lb per square inch.

Another recent development of this firm for mine use is a hydraulic ram for use with face conveyors. This ram has an independent control valve unit which can be housed in a channel section attached to the gobside plate and coupled to the rear of the ram by pressure tubing. The valve lever has three settings—ram in, ram out and neutral—and when it is in the neutral position the ram can be disconnected without loss of oil from the hydraulic system.

[Reply Card No. E7111]

Weatherproofed Switch

A NEW switch, known as the "Greasfil," manufactured for aircraft applications by Dowty Nucleonics, Ltd., Brockhampton Park, Andoversford, Glos, is completely filled with a silicone compound so as to be impervious to rain, ice, mud and similar hazards. The filling also allows efficient operation irrespective of altitude or weather conditions, and in an ambient temperature range from +70 deg. to −55 deg. Cent. The compound lubricates the action and provides hydraulic damping of shock loads. An internal rubber diaphragm accommodates grease displacement during operation. The switch is supplied charged with M.S.4 silicone compound and a special grease gun is provided for use on installation and subsequent re-greasing. A non-standard grease nipple ensures that accidental injection by any other than the correct gun is prevented. Further silicone compound is added after installation until the compound is seen to extrude from the tip of the terminal grommet, so that the switch terminals are completely protected. Re-greasing is normally only necessary at major overhaul intervals. In order to ensure the necessary heavy contact pressure, the switch has a positive contact action instead of quick make-and-break, the action being transmitted direct to the contacts instead of through a system of springs. Thus a displacement rather than a force input is necessary; a long-stroke wiping action results in low millivolt drop. Positive action entails a slight sacrifice in current-breaking capacity, but the "Greasfil" switch is suitable for a wide range of aircraft applications and is mechanically interchangeable with the maker's "Dowmic" switch.



Grease-filled switch for aircraft installations with special charging nipple

[Reply Card No. E7112]

Mobile Rock Drill

A SELF-PROPELLED machine for drilling holes 4½in–5in diameter to depths of 250ft has been introduced by the Reich drill division of the Consolidated Pneumatic Tool Company, Ltd., 232, Dawes Road, London, S.W.6. This equipment is of the "down the hole" design in which the pneumatic hammer is situated at the end of a string of drilling rods and immediately behind the bit. By this arrangement the hammer develops the maximum percussive effect immediately behind the bit and no energy is dissipated by transmitting its blows through a string of rods.

Self-propelled "down-the-hole" rock drill equipment

The equipment is powered by a 31 b.h.p. Ford "P.3" three-cylinder diesel engine which is coupled directly to three hydraulic pumps operating in parallel and providing pressure fluid for the rotary drilling head, the feed cylinders and propelling motor.

The chassis on which the equipment is mounted is of welded channel steel construction and is carried on four pneumatic tyred wheels, one pair of which can be steered from a driver's seat. Drive to the rear axle is transmitted from a hydraulic motor and a Croft torque-arm reducing gear through a roller chain. A trunnion-mounted mast carrier bracket on a tubular steel mounting at the rear of the chassis can be swung through 160 deg. by means of three hydraulic pistons to position and hold the mast assembly at any required working angle.

The drilling mast mounted on the carrier bracket is an assembly of braced welded steel channels which form a rigid rectangular slide, 13ft 3in long, for the drilling unit. A sliding bracket on the drilling mast carries the head gear the hydraulic motor of which rotates the drill rod string through a reduction gearbox. This drive develops a torque of 10,500 lb at 45 r.p.m. during the drilling operation. A fixed table at the foot of the mast gives a rigid support to the drill rods when centring or starting a hole.

During the drilling operation the necessary thrust is imparted to the rods by a hydraulic piston coupled to the rotary head bracket through steel cables. These cables pass over a double purchase pulley which doubles the 5ft 6in piston stroke to give a bracket stroke of 11ft—sufficient to permit the use of 10ft long extension rods as drilling proceeds.

Compressed air, for the operation of the hammer and for flushing of dust and chippings, is derived from one of the maker's rotary power vane compressors which is towed behind the equipment. During drilling the air supply is taken through a 1¼in diameter hose to a connection on the drill chassis and to an air swivel on the top of the drill head motor box whence it passes to the collar of the first of the drill rods. The 2in bore of the drill rod string ensures the minimum amount of pressure loss in air transit to the bit. Two sizes of "down-the-hole" air-operated hammers are available and two sizes of bit can be supplied with each hammer. The available bit sizes are 4½in, 4¾in and 5in. The design of the hammers is such that a high velocity blast of air, is passed up between the hammer and the wall of the bore to clear the chippings from the hole.

We are informed that when drilling with this equipment in carboniferous limestone a bit life has

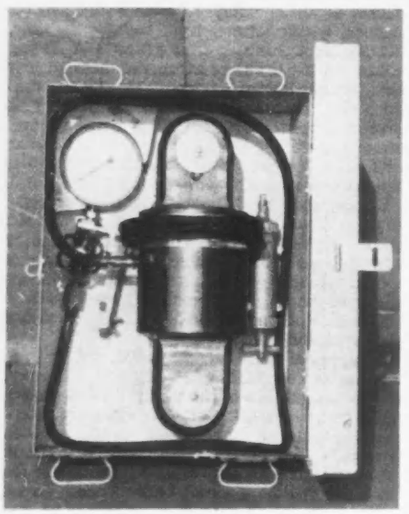
been obtained in excess of 4000ft if bits were reground at 450ft intervals. In this formation an average penetration rate of 45ft per hour was attained.

[Reply Card No. E7113]

100,000 lb Hydraulic Dynamometer

OVER twenty years ago, the National Institute of Agricultural Engineering produced a hydraulic dynamometer for its own use in the testing of tractors and the measurement of implement draught. Subsequently, the Institute received inquiries from many parts of the world for instruments for checking the performance of tractors in the field and other work. The only way in which such requests could be met was by handing over a set of drawings so that inquirers could either make the instruments or get them made, generally on a "one off" basis.

This procedure did not prove particularly satisfactory and for the past ten years or so the dynamometers have been made by Roadless Traction, Ltd., Hounslow, Middlesex, each of the instruments being checked and calibrated by the N.I.A.E. Under this arrangement, the firm has been producing dynamometers for readings up to 10,000 lb and 40,000 lb. Recently, however, there has been a demand for an instrument capable of recording up to 100,000 lb; the N.I.A.E. produced the design and Roadless Traction, Ltd., is manufacturing it. This dynamometer, which is illustrated herewith, is required for a number of purposes including locomotive drawbar tests and field tests of heavy tracklaying tractors and tanks. Provision has therefore been made in its design for a fair amount of rough handling during use in a field whilst, at the same time, maintaining a high degree of accuracy. On account of the largely unavoidable delicacy of the gauge which shows the drawbar pull, this must be coupled to the dynamometer by an appropriate length of flexible hose so that the gauge itself can be placed where it can be easily read but where it is safe from damage. The piston and cylinder are closely ground to size and are then given a mirror finish, which, the makers claim, has resulted in the high efficiency shown during recent tests at the National Physical Laboratory. Before verification, the instrument was loaded three times in tension to 100,000 lb foot. Two tests were made at temperatures varying



100,000 lb hydraulic dynamometer

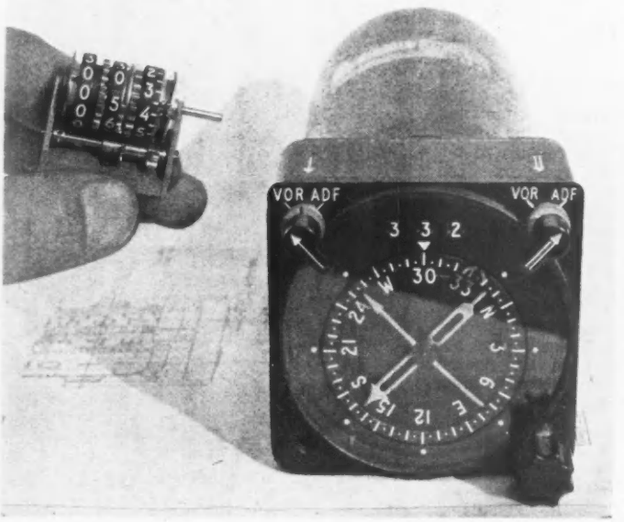
between 20·6 deg. and 19·8 deg. Cent. The piston of the device was then rotated through 90 deg. and a third test made at a temperature of 20 deg. Cent. The N.P.L. report shows that in all three tests, the standard of accuracy achieved at loads from 30,000 lb to 100,000 lb exceeded 99 per cent.

[Reply Card No. E7121]

Continuously Running Counter

FOR a new air navigation instrument, the Radial Magnetic Selector, which will display the heading of the aircraft derived from the gyro compass, the bearings of two radio transmitters (either VOR—v.h.f. omni-directional range—or A.D.F.—aircraft direction finding—beacons) and also the course it is desired to steer, Smiths Aviation Division has evolved a simple counter device for the continuous presentation of bearings. The counter runs continuously, not in steps, and the units drum is graduated in ½ deg. divisions, so that it can be read to ¼ deg. The operating torque has been minimised to allow driving from electric servo systems, and at room temperature it is 10 gm. centimetre only. The mechanism is so arranged that after counting to 359 deg. it starts again at 000.

The units and tens drums are numbered in the usual way, and the tens are driven from the units by the layshaft seen in front of the counter. Normally the tens advance one figure for one revolution, but when "359" is reached the cam plate seen on the left of the hundreds drum moves the layshaft to the right to engage an additional set of teeth on the units wheel. by virtue of which the two drums move together, "6" (tens) and "2" changing to "0" and "6." The figures "6," "7," "8" and "9" are prevented from appearing by a "0," projecting over the tens drum, which is carried on the hundreds drum. The preceding description has shown that the tens counter makes 4·1 revolutions for 370 unit inputs, or, in effect, four revolutions for 360 deg., so that it is necessary for the hundreds drum to execute one turn for four turns of the tens drum. This is achieved by having twelve figures on the hundreds drum and advancing it three places for each revolution



Instrument and bearing display device

of the tens drum, the layshaft for this purpose being behind the gear. The hundreds drum is advanced one place as "5" gives way to "6" on the tens drum—this is necessary to make "359" change to "000"—and two places as "9" changes to "1."

The instrument will function between −40 deg. and 70 deg. Cent., and not suffer permanent damage between −60 deg. and 100 deg. Cent. It is designed to resist accelerations of the order of 25 *g*.

[Reply Card No. E7122]

Organic Heat Transfer Medium

THERE has been added to the range of phenol derivatives made by the Heavy Organic Chemicals Division of Imperial Chemical Industries, Ltd., an industrial heat transfer medium. High heat transfer coefficients are claimed for "Thermex" which is a pale yellow liquid, consisting of the eutectic mixture of diphenyl oxide and diphenyl. It is practically insoluble in water, but dissolves readily in organic solvents. In view of its high boiling point and low freezing point, coupled with its non-corrosiveness and high thermal stability at temperatures up to 400 deg. Cent., this mixture is suitable for both liquid-phase and vapour-phase heating at temperatures well above those at which steam could be economically employed. For instance, at 350 deg. Cent. steam would condense at 2385 lb per square inch against 80 lb per square inch for the organic mixture.

Typical Properties :

Diphenyl oxide content, per cent by weight	73·5
Diphenyl content, per cent by weight	26·5
Crystallising point, deg. Cent.	12
Boiling point at 760mm Hg, deg. Cent.	255
Density at 20 deg. Cent., g/ml.	1·06
Flash point (Pensky-Martens, closed cup), deg. Cent.	115
Water content, per cent by weight	0·02
Ash, per cent by weight	0·001

It is claimed that "Thermex," even when employed for long periods at temperatures as high as 400 deg. Cent., causes no more than a negligible corrosion of any of the metals which are commonly used in plant heating systems.

"Thermex" has a very low order of toxicity, and no toxic effects on humans have been recorded. Neither the liquid nor the vapour causes any appreciable irritation of the skin, nose or eyes; hence no special precautions are necessary at ordinary temperatures. As in the case of all organic solvents, however, splashes on the skin and in the eye should be removed immediately by washing with plenty of water.

"Thermex" has a strong and persistent geranium-like odour, which is particularly evident at high temperatures and which is useful in locating even minor leaks in plant systems. This characteristic odour is readily detectable at concentrations much less than 10 p.p.m., which is very close to the saturated vapour concentration at normal atmospheric temperatures. To ensure comfortable working conditions, the concentration of vapour in the atmosphere should preferably be kept below about 2 p.p.m.

Although "Thermex" is combustible at elevated temperatures, its high flash point minimises the risk of fire. Vapour escaping into the atmosphere from a small plant leak rapidly condenses and cools to a temperature well below the flash point. The risk of an explosion occurring in a "Thermex"/air mixture is negligible, because the concentration range in which an explosion is possible lies between 0·99 and 3·36 per cent by volume of "Thermex" vapour in the vapour/air mixture, and these vapour proportions correspond respectively to saturation temperatures of 107 deg. and 143 deg. Cent. Moreover, an explosion could not be initiated by an ignition source below 600 deg. Cent.

Although natural circulation is in practice sufficient for many industrial applications, the use of forced-circulation systems for liquid-phase heating is preferable at high operating temperatures, in order to ensure accurate control of heat input and to avoid local over-heating. In vapour-phase systems, the use of forced circulation provides adequate and uniform flow over the entire heating surface, and helps to minimise thermal degradation of the medium.

The presence of extraneous water in the system can, we are advised, be rather dangerous, owing to the high vapour pressure of water at temperatures above 100 deg. Cent. The relative insolubility of water in "Thermex," however, enables it to be removed by decantation. Alternatively, the water may be vaporised and vented to atmosphere before the plant system is brought up to its normal working temperature.

[Reply Card No. E 7123]

Industrial and Labour Notes

Trade Unions and Automation

One of the papers presented to the British Institute of Management's national conference, at Harrogate last week, was by Mr. J. A. Birch, on the reaction of the trade unions to automation. He said that interest in the subject of automation appeared to reach a peak three or four years ago. The imagination was caught by the vision of the "push-button factory" and this had resulted in some lively discussions in trade union circles. Two possible, if somewhat contradictory, implications had been seized upon, Mr. Birch commented. On the one hand, there was the prospect of phenomenal increases in the production of wealth from manufacturing industry's output of both capital and consumer goods. On the other hand, there was the fear of large-scale redundancy and unemployment as a result of a big acceleration in the displacement of labour by the new machines.

Mr. Birch went on to stress the importance of anticipating the human problems arising from automation by consulting workpeople through the trade unions, from the beginning. The development of joint consultative machinery outside the main stream of trade union–employer relationships, he said, might well require to be re-examined. Re-training and instruction were essential if workers were to be transferred from one job to another and, in the long term, there would be a growing demand for a knowledge of planning, designing, production control and technical and specialist subjects. But, Mr. Birch added, the unions would be concerned not just with redundancy but with the protection of wage rates and earnings. It was reasonable to expect an improvement in working conditions as modern machinery took over routine and repetitive tasks.

Mr. Birch emphasised, however, that the trade unions could not expect a modern approach by others to the social problems of industrial change without being prepared to reconsider their own policy and functions. In the field of industrial wage bargaining, he said, the limitations of traditional policy and attitudes would become more and more apparent. The structure of many industrial agreements on wages and conditions of labour might, in many cases, require to be substantially revised. What was of great concern to the trade union movement, Mr. Birch remarked, was the widely different rate at which productivity could increase in different industries and trades. The scope for increased earnings and improved conditions, such as shorter working hours, might widen fairly rapidly in some industries while it might remain constant or even contract in others.

Engineering Wages and Hours

On Tuesday, the Engineering and Allied Employers' National Federation replied to the claims for a wage increase of £1 a week and for the introduction of a forty-hour week in the engineering industry, without loss of pay. The claims were submitted in September by the Confederation of Shipbuilding and Engineering Unions.

In presenting the Federation's statement, Mr. B. Macarty, the director, said that, in the period 1948–58, earnings rose by 93 per cent, wage rates by 71 per cent and retail prices by 56 per cent. The contention that since the war profits in the engineering industry had risen far in excess of the rise in wage rates was completely unacceptable. In 1949, wages and salaries in the engineering, shipbuilding and electrical goods industries represented 64·2 per cent of the net output and in 1957 they were 64·1 per cent; in vehicles, the percentages were 71·5 in 1949 and 70 in 1957. There had been a slight reduction in the number of the average hours worked, about half an hour less comparing June, 1959, with March, 1958, but the average was still over forty-eight a week. Despite this slight shortening of hours, Mr. Macarty commented, earnings of all classes showed a marked increase. He went on to say that the Federation was unable to concede the union claim that the rate of wages for women should be not less than that for the male labourer. Manual work clearly established as man's work and done by women was paid for at the man's rate and had been so paid since 1940.

Dealing with the demand for a forty-hour week, Mr. Macarty said that the economic climate must be propitious and likely to continue so before it could be introduced. There must be certainty that the outcome of such a change would not result in a lowering of the real value of wages or the general standard of living by causing another twist in the spiral of inflation. The figures for the number of hours worked in the engineering industry had remained remarkably constant for more than thirty years; there had been a very slight reduction in the number of hours of overtime worked but it still averaged over four hours a week. Inquiries had revealed that about 60 per cent of the men employed by the Federation's member firms were working overtime in June last, a figure only very slightly below that recorded for a year previously. In dealing with the question of hours, the Federation felt it was necessary to refer to certain practices which undoubtedly militated against the effective use of working time. Mr. Macarty mentioned in this context a condition in a national industrial agreement between the Swedish metal trades employers and the metal workers' and foundry workers' unions. It emphasised the need for really effective working hours. The Federation, Mr. Macarty added, would not wish to impose conditions in terms such as those included in the Swedish agreement. But it was essential that there should be joint acceptance of the need to deal with those practices which militated against the effective use of all working time.

Engineering Production

According to statistics collected by the Board of Trade, production in the engineering and electrical goods industries in August showed the effect of the seasonal fall during the holiday period but was 4 per cent higher than in August last year. Estimates for September indicate that there was a similar increase in the production rate when compared with a year earlier.

The volume of total orders in hand at the end of August reverted to the end of June level; there has been virtually no change since the end of March last. On the other hand, export orders have increased slightly in recent months though they are still below the 1958 level for the comparable period. The Board of Trade says that the stability of orders in hand this year, in contrast with the fall throughout last year, and coupled with increasing production, indicates some increase in the rate at which new orders have been received. Taking 1954 as 100, the index of production in the engineering and electrical goods industries was 97 at the end of August, the index number for exports being 116.

Coal

The Coal Industry Bill was given its second reading in the House of Commons on Monday. The purpose of the measure is to extend the borrowing powers of the National Coal Board in the period up to the end of 1965 to a new limit of £700 million. After that, the limit may be increased by an Order to a final figure of £750 million. The Board, however, is not to be permitted to borrow more than £75,000,000 in any one year.

Moving the second reading, the Minister of Power, Mr. Richard Wood, explained that the Bill was irreparably connected with the "Revised Plan for Coal." On the basis of that document, the Coal Board estimated that its capital expenditure between 1960 and 1965 would be £511 million. The Board believed that it could raise £375 million from its internal resources, leaving a sum of £136 million to be borrowed. Existing powers permitted the Board to borrow £60,000,000 so that the additional sum needed was £76,000,000.

Mr. Wood went on to say that he believed there was a need for a broad examination of the country's fuel and power position. The present advocates of a national fuel policy were concerned, not unnaturally, with the difficulties or the likely future difficulties of the coal mining industry. Therefore, the Minister remarked, it had been suggested to him that the fuel policy to-day should be something on the following lines. If the total fuel requirements of the nation were so many tons of coal equivalent, the Government should itself make plans to ensure that a certain proportion of those requirements were met by coal and certain smaller proportions were met by oil and nuclear power. But, the Minister continued, there was one major difficulty in the way of that, the difficulty being that fuel needs varied not only from industry to industry but from one consumer to another. It was quite impossible to lay down a simple guide about what fuel was the most economical for general use. It was impossible to escape the conclusion that Government intervention would impose upon consumers costs about which the Government, when imposing them, would have no idea whatever, because it was quite impossible to see exactly where the policy of guaranteeing certain shares for certain fuels would impinge on individual fuel users. There was the further important point, the Minister added, that the denial of freedom of choice to consumers and the compulsion to use certain fuels rather than others was not only industrially undesirable, but was also humanly immeasurable and indefinable.

Swiss-Built Locomotives for Roumania

SIX 2100 h.p. diesel-electric locomotives for the Roumanian State Railways are being built in Switzerland by a consortium of three firms. The diesel power plant is being supplied by Sulzer Brothers, Ltd., Winterthur; the electrical equipment by Brown, Boveri and Co., Ltd., Baden; and the mechanical parts by the Swiss Locomotive and Machine Works, Winterthur. Similar diesel-electric installations are being supplied by Sulzer and Brown, Boveri for ten more locomotives of the same series under construction in Roumania.

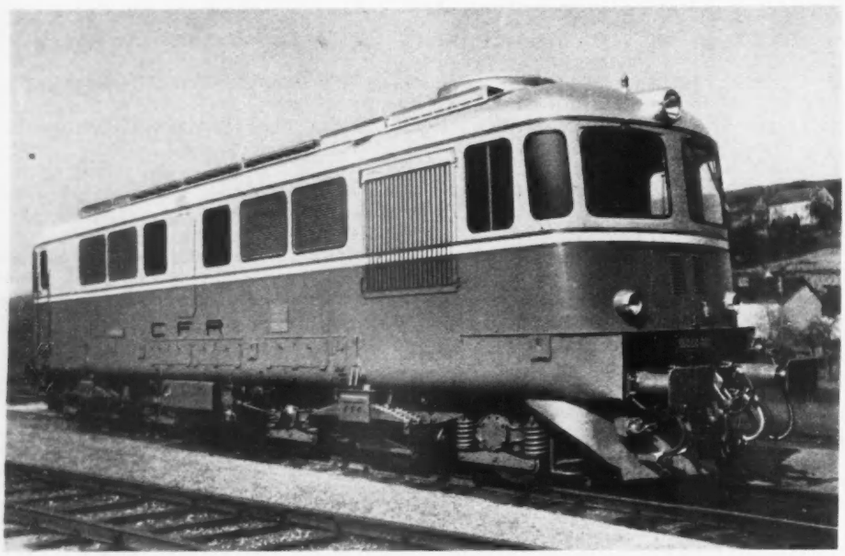


Fig. 1—One of six 2100 h.p. diesel-electric locomotives being built by a group of three Swiss firms for the Roumanian State Railways

The locomotives have the C_0–C_0 wheel arrangement. Fig. 1 shows one of the six built in Switzerland. The diesel engine is the Sulzer twelve-cylinder, twin-bank 12 LDA 28 with exhaust gas turbo-charger, a development of the first Sulzer twin-bank engines supplied in 1938 for double-unit locomotives of the French National Railways and Roumanian State Railways, in which the engines had a continuous rating of 1900 h.p. In the present locomotives the 12 LDA 28 engines are rated continuously for Roumanian conditions of barometric pressure and temperature at 2100 h.p. at 750 r.p.m. Similar engines are being supplied for 147 British Railways locomotives (see our issue of May 1, 1959), in which some will be continuously rated at 2300 h.p. and others at 2500 h.p.

Roumanian conditions have also made it necessary to provide for warming the cooling water when a locomotive stands in the open for long periods with the engine shut off, and for pre-heating the lubricating oil. For these purposes a "Vapor" heating unit is installed and a three-way cock enables it to be connected either to the cooling water circuit or to a separate circuit for heating the water in the oil-cooler alone.

The two three-axle motor bogies of the Swiss-built locomotives are interconnected by an S.L.M. transverse coupling which reduces flange wear by ensuring that the bogies take up the most favourable positions on curves. No tractive forces are transmitted by this coupling, these forces being taken by the kingpins; the buffers and drawgear are fitted to the headstocks of the locomotive body. Friedman flange lubrication is applied to the wheels on the two outer axles of each bogie, lubricant being fed to the nozzles by an axle-driven pump.

Fig. 2 shows the side bearers, carried on lateral double-leaf springs, which take the body weight. The springs are connected at their ends by transverse swing bolsters slung from the bogie frame so as to allow sideways displacement of the locomotive body up to about $\pm 1\frac{1}{4}$in. Longitudinal connection between the springs and the bogie frame is made by means of links, one of which is seen in the drawing. The body bearing surfaces consist of V-shaped case-hardened steel shoes running on bronze slides which are curved to conform with a circle having its centre in the middle of the bogie. The shoes can turn about a vertical axis and the slides are supported on segments so as to allow vertical turning movements of the bogie in respect to the locomotive body.

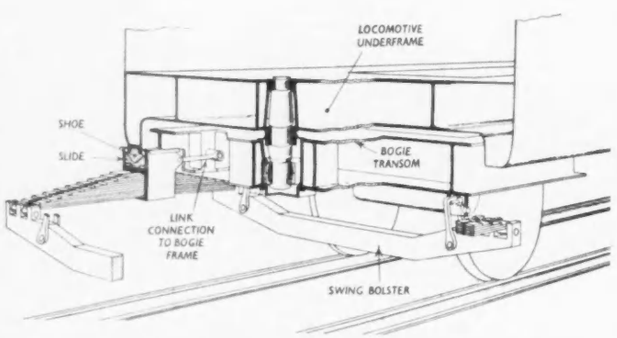


Fig. 2—Secondary suspension of locomotive

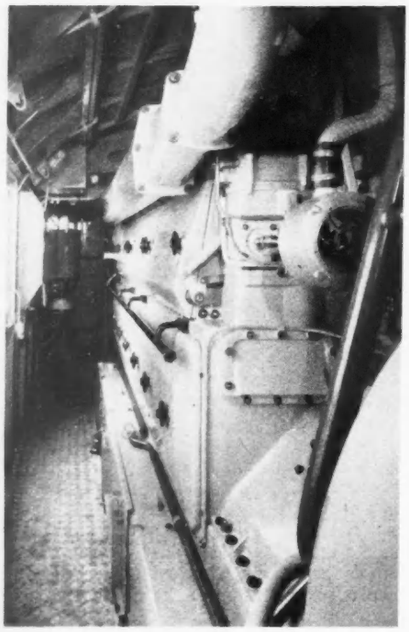


Fig. 3—Engine-room interior. The servo-operated load regulator and governor are in the foreground

Drawbar and buffing forces are transmitted to the body by a kingpin in each bogie, the upper end of which is fixed to the underframe while the lower end, which is case-hardened and ground, is embraced by a spherical bronze bush lying in a case-hardened steel bearing in a transom of the bogie frame. The bearing can move sideways in an oil bath by $\pm 1\frac{3}{4}$in.

Three axle-hung, nose-suspended traction motors are mounted in each bogie. Two pairs of coil springs are incorporated in the nose suspensions and sideways movement on the axles is restrained by rods with "Silentbloc" mountings on the motors and on the bogie frame. The motors are normally forced-ventilated, but a built-in fan maintains air circulation in the normal direction when the locomotive is coasting with the engine shut down. This prevents convectional circulation of the heat stored in the motors from taking place in the opposite direction and causing brake dust to be drawn in from underneath the bogies.

The traction motors are connected in series-parallel across the main generator, which is a single-bearing machine coupled directly to the output shaft of the engine gearbox, and runs at 1080 r.p.m. for an engine speed of 750 r.p.m. An auxiliary generator is partly recessed into the end of the main generator armature.

On the first three controller notches the generator output is controlled by steps of fixed resistance while the engine runs at idling speed. Notch 4 brings the Sulzer servo-operated 40-step load regulator into action and this adjusts the generator excitation according to load throughout the subsequent acceleration of the diesel engine. This is a continuous process as the controller handwheel is moved further towards maximum, although the handwheel moves in twenty-four definite steps for the driver's guidance in selecting a particular setting. If any axle of the locomotive slips, the natural tendency of the load regulator to detect a decrease in load and to increase excitation is offset by the automatic energisation of an electromagnet acting on the lever controlling the slide valve through which oil is admitted to the servo motor. This returns the regulator to its maximum resistance setting (step 40). An anti-slip application of the brake s made simultaneously.

Two stages of field-weakening by means of diverter resistances are brought in automatically. The first is initiated, subject to a relay responsive to generator voltage, when the load regulator is driven past its maximum excitation setting

and operates a limit switch. Step 2 follows after a time delay if the regulator again passes maximum excitation. The weak-field relays are energised through two contact tracks traversed by the load regulator arm. If, after weak-field has been switched in, the traction current increases to the extent that the forty-step regulator is driven back past step 26, the arm leaves the track feeding the second weak-field relay and the corresponding contactor opens. Further reduction of excitation past step 28 causes full field to be restored at the traction motors.

Fig. 3 shows the width of the side corridors in the engine-room, both of which are similarly unobstructed adjacent to the engine-generator set. Two traction motor blowers are placed transversely at each end of the set, and the water/oil heater, fuel transfer and oil-priming pump set, and air compressor are against the side wall in the other corridor, but clear of the power equipment. The main air reservoir and electrical control cubicle are at one end of the engine, and the radiators, with Behr hydrostatic fan drive, at the other. A motor-generator set and cooling water pump are placed inside the radiator tunnel.

The overall width of the body of this 4ft 8½in gauge locomotive is 9ft 10in, and the length over buffers 55ft 9in. The locomotive in working order weighs 112·2 tons and will exert a starting tractive effort af 70,500 lb. The one-hour T.E. rating is 49,500 lb at 11·5 m.p.h. and the corresponding continuous rating 44,200 lb at 13·4 m.p.h. Maximum speed is 62 m.p.h. Two or more locomotives may be operated in multiple. During acceptance trials in Switzerland the first locomotive of the series is reported to have accelerated a 550-tonne train from a standstill to 14 m.p.h. in about three minutes up a gradient of 1 in 38½ with continuous curvature.

Professor Walther Bauersfeld

Professor Walther Bauersfeld, who died on October 28, in Heidenheim a.d. Brenz, was one of the foremost German scientists and technologists. Born in Berlin on January 23, 1879, he received his technical education at the Technical University of Berlin-Charlottenburg, and subsequently remained there for several years as assistant of Professor E. Reichel who held the chair of mechanical engineering and water turbines. On August 1, 1905, Bauersfeld joined the firm of Carl Zeiss, Jena, as design engineer, and became a member of the board in 1908. From 1927 until 1945, Professor Dr. Bauersfeld occupied a chair for special fields of technical physics at Jena University; after 1945, he taught precision mechanics at the Technical University of Stuttgart. His chief contributions, however, consist of his many inventions—his name is found on over 120 patents—and in his achievements as an industrialist.

Of his scientific and design work, some of the most outstanding examples may be mentioned here. He was the inventor of the auxiliary lens system for the stereo-planigraph; in kinematography he developed means for optical image correction. His paper "The foundation of the calculation of high-speed gyroscopes" formed the basis of the further development of Kaplan turbines. A method for producing high-precision circular scales has found an important application to theodolites. Other mechanical inventions were in connection with gearing, and with highly accurate roller bearings. An important aid to surgeons is the "Pantophot" theatre lamp which does not cast any shadows. His epidiascope "Belshazzar" permits the projection of words written on a small surface and so avoids the necessity for lecturers having to write on large blackboards. Especially numerous were his improvements and developments of the microscope; one recalls the ingenious re-arrangement of the layout of the instrument, incorporating a fixed stage and an adjustable tube.

An invention which has become very widely known among the general public was the projection planetarium. A request had been made in 1913 by the German Museum in Munich, an institution corresponding to the Science Museum in South Kensington, for such an equipment which, following traditional ideas, was to represent the fixed stars on the inside of a large sphere, and the planetary systems by means of mechanically moved illuminated bodies. An arrangement somewhat along these lines was eventually supplied by Zeiss to the Museum, but in the meantime Bauersfeld had hit upon the much more compact and adaptable solution of optically projecting the stars and planets upon the interior of a large hemispherical dome. The comparatively small instrument comprised a number of rotating and fixed projectors, for projecting respectively the planets and stars, while the apparent motion of the sky was realised by the rotation of the instrument as a whole. Faced with the problem of designing a suitable dome, Professor Bauersfeld took a leading part, together with Dr. Dischinger and others, in originating the important Zeiss-Dywidag method of shell construction.

As an industrialist, Professor Bauersfeld was active in the management and expansion of the Carl Zeiss Foundation which he continued to lead in the spirit of its originator, Ernst Abbé. When, after 1945, the Foundation was transferred to the German Federal Republic, it was in a great measure his experience and initiative which enabled the Foundation to resume its work at Oberkochen and, starting from nothing, to achieve within a few years again a position of eminence among optical manufacturers. Besides many other honours, Professor Bauersfeld in 1952 received the Grashof Medal, the highest award bestowed by the Association of German Engineers. In 1957, he became the first German citizen to be awarded the James Watt International Medal by the Institution of Mechanical Engineers.

Light Aircraft

We have received details of the four-seater aircraft WA40 "Super IV Sancy" produced by Société des Etablissements Benjamin Wassmer, Issoire (Head office, 13, rue Etienne-Dolet, Paris). The "Super IV Sancy" has a span of 10m, a length of 7·6m, a height of 2·6m, and a wing area of 16 square metres. It weighs 650kg when empty, and has an all-up weight of 1200kg. Powered by a 180 h.p. Lycoming engine, it has a maximum speed of 285km per hour and a cruising speed of 265km per hour at a height of 2400m; its maximum climbing rate is 5m per second. With a fuel consumption of 38 litres per hour, it can remain in flight for five hours. Our illustration shows the layout of this low-wing monoplane which is equipped with retractable tricycle undercarriage. The air conditioned cabin has seating for the pilot and co-pilot side-by-side, with a double seat in the back. The plastic cabin top is opened by sliding it to the rear, when the cabin is fully uncovered.

Wassmer WA40 "Super IV" four-seater aircraft

Federation Europeenne de la Manutention

The Seventh Annual Congress of the Federation Europeenne de la Manutention (F.E.M.) was held at Lucerne, Switzerland, from September 21 to 25, 1959, and was attended by about 250 delegates from many European countries including the United Kingdom.

The British crane-making industry was well represented at the meetings of those Sections of the Federation which dealt with heavy cranes (Section I) and mobile cranes (Section V). At present, Section I is preparing a European Standard Specification covering the design requirements of overhead travelling cranes and jib cranes. The Technical Sub-Committee has also recently completed the drafting of an illustrated Terminology in six languages of the descriptions used in each country for the various structural and mechanical components and accessories of heavy cranes. One of the committees of this Section is concerned with tower cranes for use in building, mainly as regards safety in operation and the standardisation of such matters as track centres, capacities, radii, &c. Another deals with economic matters of special concern to crane manufacturers. Terms and conditions of contract in relation to materials handling equipment as a whole are, however, covered by a special committee of the Federation which was set up at Lucerne and on which the Section will be represented.

In Section V the work up to date has also been mainly concerned with the drafting of a European Standard Specification covering the design requirements for self-propelled mobile cranes on pneumatic tyres or crawler tracks, and with the publication of an illustrated, multi-language Terminology of the components, parts and types of mobile cranes. The outline of the Standard Specification has been agreed, and it is hoped to have the first draft ready by June next year. The "Terminology" is to be published in the near future. Inquiries for copies should be addressed either to the Federation's headquarters at 10, Avenue Hoche, Paris VIII, or to the Association of Crane Makers at Sardinia House, 52, Lincoln's Inn Fields, London, W.C.2.

German Travelling Exhibition

The Verein Deutscher Ingenieure (V.D.I.—Association of German Engineers) has transformed into a travelling exhibition, an exhibition, "Correct Design Practice for Metal Working," first presented in March by the Institute of Machine Tools and Metal Working Technology (Professor Dr.-Ing. O. Kienzle) of Hanover Technical University. By the end of this year, the exhibition will have been shown in nine major industrial towns in the Federal Republic. It is intended for designers, as well as production engineers and students of engineering, and aims at giving a synopsis of the most important processes, which are illustrated by means of several hundred examples. The exhibition is held for approximately one to two weeks at each centre. In this connection the V.D.I. is arranging at certain of the principal towns a two-day course of lectures given by well-known specialists.

Translations of German Industrial Standards

The German Standards Committee (Deutscher Normenausschuss), Berlin, W.15, has established a special department to prepare translations of German industrial standards in English. So far, 500 English translations have been made.

New lists of the translations available may be obtained free of charge from the Beuth-Vertrieb G.m.b.H., Berlin, W.15, Uhlandstr. 175.

Dielectric Research at the National Bureau of Standards

BY OUR AMERICAN EDITOR

The National Bureau of Standards at present conducts a programme of research which increases the applicability of dielectrics by explaining observed dielectric phenomena and by improving the accuracy of dielectric measurements. Both these aspects are of primary importance in the present demand for materials tailored to the special needs of modern technology. Furthermore, the information obtained in the Bureau's broad investigation extends to all electrical and electromagnetic applications.

TO provide a better understanding of the properties exhibited by dielectric materials, the National Bureau of Standards is currently conducting a programme of fundamental research sponsored in part by the U.S. Department of Defence. The primary objectives of this programme are to explain observed dielectric phenomena and to develop theories which can be used to predict the behaviour of certain materials. In most of the work, a solid state approach is employed to probe the molecular behaviour responsible for dielectric phenomena. These studies are complemented by efforts to improve the accuracy of dielectric measurements in the fields of electricity, electromagnetic waves, electronics, solid state research, polymer studies and physical chemistry.

During the past few years, demands for dielectric materials designed for specific applications have become more and more insistent. In the missile and aircraft fields, for example, dielectrics with electrical properties that are relatively independent of temperature are needed. To create dielectrics for special purposes in this way, the effects of various physical conditions on electrical properties must be determined, and the relationship between molecular behaviour and electrical properties must also be established. Programmes of dielectric studies, carried out by the Bureau's Dielectrics Section and ferroelectricity group in Washington, and the Radio and Microwave Materials Section of the Boulder Laboratories in Colorado, provide concepts for this work.

Basic Dielectric Studies

Many dielectric phenomena are associated with a property known as "electric polarisation." Part of this electric polarisation is due to a displacement of the bound charges in molecules when a voltage is applied. Little or no dielectric loss is associated with this contribution. Electric polarisation can also take the form of interfacial polarisation, i.e. polarisation arising from the movement of electric charges on the interface between two discrete phases. Still other electric polarisation arises from the presence of orientable permanent electric dipoles in molecules. Loss caused by "frictional" restraint on the motions of the ions or dipoles is associated with these last two types of polarisation. The Dielectrics Section is interested primarily in dipole polarisation because it provides a basis for studying both intermolecular and intramolecular motions in such important materials as high polymers and for establishing the relationships which exist between the electrical characteristics and certain chemical and physical characteristics. Dipole polarisation also is a factor in the dielectric spectrum in the radio frequency range. It is involved in the non-resonant microwave spectroscopy of gases carried on by the Radio and Microwave Materials Section.

When the loss index or loss factor of a material containing dipoles is plotted against the logarithm of the applied frequency, a maximum caused by a relaxation mechanism occurs at some particular frequency value. The height of this maximum, the frequency at which it occurs, the breadth of the loss peak, and the change of these parameters with temperature (Fig. 1) provide information which leads to a fundamental understanding of many of the important electrical properties of the material. Such parameters can also be correlated with other properties, such as mechanical relaxation. To make measurements over a wide range of frequencies and temperature, a wide variety of special bridges, circuits, holders, transmission lines, resonant cavities and cells have been put into use. One example is illustrated in Fig. 2. Dielectric constants and dissipation factors are measured at both the Washington Laboratories and the Boulder Laboratories over a frequency range of 0·1 to 10^{10} c/s at temperatures from −100 deg. to +500 deg. Cent. In addition, facilities for millimetre-wave work are available at Boulder and studies have been made at the low frequency end of the dielectric spectrum, involving frequencies whose periods are days in length.

Just as frequency determines the dielectric measuring technique that must be used, temperature dictates the structure of dielectric cells. The Bureau has developed several systems (Fig. 3). Among these are dielectric cells with micrometer-electrode holders (Fig. 5) for use at temperatures up to 500 deg. Cent. and down to −196 deg. Cent. In such holders, two electrodes, one movable and one stationary, contact the specimen, and a precision micrometer determines the position of the movable electrode. To study materials that pass from liquid form to solid form in the temperature range of interest, a "fusion cell" (Fig. 4) has been designed. This

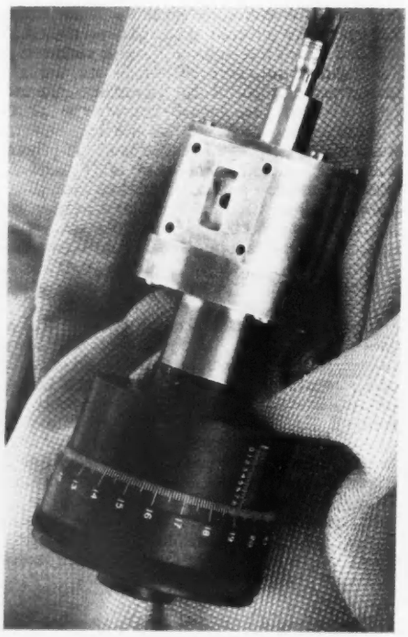


Fig. 2—Wavemeter for dielectric measurements having an accuracy of about three parts in a million

is similar to the other holders but allows the material in liquid phase to be held in the space between and around the electrodes. It applies pressure to the movable electrode as the sample is solidifying, thus preventing voids from forming as the material contracts. Work is presently under way to determine the effects of solidification on the electrical properties of materials such as 2, 2-dinitropropane, an interesting, nearly spherical molecule, that undergoes rotation in the solid state.

To study materials as they make a transition from gaseous dielectric behaviour to liquid dielectric behaviour, resonant cavities for compressed gases have been developed. Studies made with these cavities show that liquid-like behaviour can set in at pressures of less than an atmosphere in cases of strong dipolar gases. Further work is being initiated which will determine dielectric losses of very low loss gases, such as sulphur hexafluoride, which very closely approximates a spherical molecule. All of this experimental work is supported by an active theoretical programme. Some of the theoretical topics under study are dipole relaxation in molecular crystals, the dielectric properties of semi-crystalline polymers and the nature of the glassy state.

In the study of crystalline non-metallic inorganic solids, carried on by the ferro-electricity group and the Radio and Microwave Materials Section of Boulder, measuring circuits similar to those mentioned are employed. These materials, however, present somewhat different problems, both theoretical and empirical. Whereas with polymeric materials it is desirable to consider the polarisation in terms of molecular structure, here crystal structure is of utmost importance. Contributions to the dielectric constant arise from electron displacement, local displacements of the nuclei forming the lattice, and migrations of these nuclei to other sites. These contributions will be affected not only by the crystal structure and orientation but also by crystalline defects, such as impurities, vacancies and domain boundaries.

A detailed study in the Boulder Laboratories of polarisation and conductivity in barium

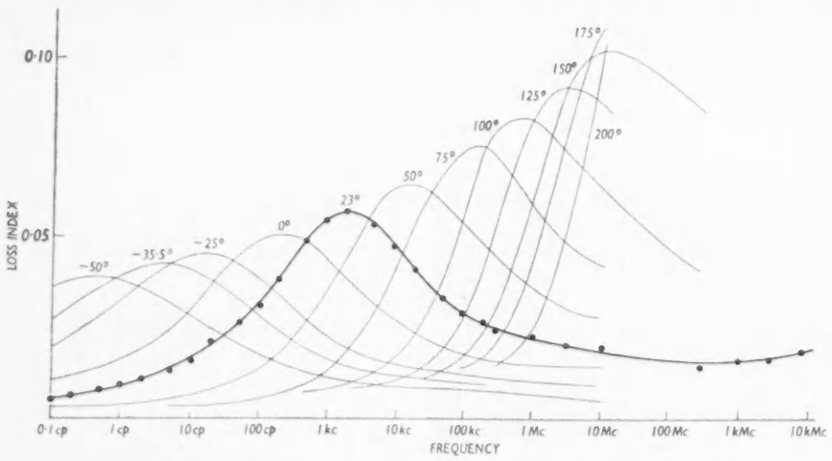


Fig. 1—Graph of the dielectric loss index *v.* frequency of polychlorotrifluoroethylene at various temperatures up to 200 deg. Cent.

titanate has led to formulations which take into account the presence of free charges near the domain walls. The charges lower the wall energy so that there is a difference between calculated and measured coercive force. The new equations explain variations in hysteresis loop shape, the dependence of conductivity on polarisation and the variation of switching time with various parameters. To extend this work, single crystals of barium titanate with various conductivities are needed (Fig. 6). It is anticipated that controlled conductivities may be achieved by bombarding crystals with electrons and measuring the change in shape of the hysteresis loop as the free electron content of the crystals changes. One major difference in experimental technique arises from the high dielectric constant of the titanate materials presently being studied. Instead of employing the micrometer holders used in the other studies, electrodes must be directly bonded to the surface of the specimen. The electrodes are made to cover the entire surface to minimise edge effects.

As ceramic materials are especially sensitive to temperature and humidity fluctuations, the studies must be carried out in a controlled environment. A constant-temperature holder has therefore been developed for use with a Schering bridge. This holder consists of an inner chamber in which nineteen specimens can be simultaneously maintained at 35·1 deg. Cent. by the circulating water from a constant-temperature bath. Between the inner chamber and an insulating outer chamber, a flow of dry nitrogen eliminates humidity effects. A second specimen holder designed for studies of the effect of temperature variation on individual specimens has also been constructed. It will be used from room temperature up to 200 deg. Cent. An added difficulty encountered in making accurate dielectric measurements on ceramics arises from the large effects of even small changes in specimen fabrication. To compensate for possible error, considerable attention is given to improving measurement techniques and characterising specimens. Two efforts are being made in this direction. First, an exploratory programme on the effects of the electrodes has resulted in the adoption of indium-gallium amalgam instead of silver as the accepted electrode material. Secondly, some single crystals to supplement ceramic specimens are being produced with the idea that the crystals will be easier to characterise.

Through these continuous efforts to improve accuracy and reliability, it is hoped that eventually the complete relationship between the composition and electrical characteristics of ceramics can be worked out. For the present, the ferro-electricity group will continue to concentrate on the titanates in general, and on barium titanate in particular. With its aim to provide a better understanding of the dielectric behaviour of a single group of interesting materials, this programme forms an integral part of the dielectric studies throughout the Bureau. While ceramics are crystalline by definition, many polymers are neither completely crystalline nor completely amorphous. Therefore, to obtain a comprehensive picture of these materials, it is necessary to determine the degree of crystallinity as a function of such variables as temperature and previous history. The degree of crystallinity is related in a simple manner to the density of the polymer. This density is easily measured by weighing the material in silicone oil. As the density of the oil at any temperature can be measured, a means for studying the amount and speed of crystallisation in the specimen at various temperatures is thus provided. A comprehensive set of measurements on the important plastic polychlorotrifluoroethylene at temperatures from −50 deg. to 250 deg. Cent. has provided such data on the relationship of specific volume to degree of crystallinity. Dielectric measurements have been made over approximately the same range of temperature and correlated with the degree of crystallinity. Similar dielectric measurements are now being made on nylon at temperatures from −100 deg. to 175 deg. Cent. These measurements are complicated by the appearance of a large d.c. conductance at the higher temperatures, and by an electret effect. An electret is a permanently polarised piece of dielectric material.

Theoretical studies, which are being conducted to explain the relationship between the electrical properties, the amount of crystallinity and the effects of temperature, will form a prominent part of the dielectric programme on semi-crystalline polymers for some time in the future. Certain crystals such as sapphire, certain molecules, such as the noble gases, and some other molecules have extremely low loss which can conveniently be studied at microwave frequencies. Also, measurements on very pure aluminium oxide reveal dissipation factors smaller than most materials now known. This demonstrates the possibility of obtaining even lower losses with very pure substances. As the theory of these losses is not yet well developed, the Radio and Microwave Materials Section is conducting theoretical studies and making new and more accurate measurements. Such investigations will have practical applications especially important at higher temperatures where low-loss materials are essentially non-existent at present. Further work in these areas is dependent upon obtaining pure materials under carefully controlled conditions.

In the interaction between electromagnetic waves and matter, conductivity properties of materials are essentially inseparable from the dielectric properties. At radio and microwave frequencies conductivity studies are therefore an important component of any dielectrics programme. In this connection, the Radio and Microwave Materials Section is investigating the tensor or directional conductivity of semiconductors such as single crystals of germanium at microwave frequencies under different physical conditions. Some important questions in the theory of solid state will be investigated in this work. It is expected that these studies will yield a better understanding of the crystal lattice forces and processes. The results may prove of value in microwave engineering if the tensor properties for radio waves are appreciable.

Among other examples of the Bureau's research in dielectrics are refractometer studies. The refractometer determines the dielectric properties of the atmosphere, which in turn determine the propagation characteristics of the troposphere, so important to radar and other means of microwave communication. The Bureau's work constitutes the background for successful applications in this field for military and other purposes. The propagation of electromagnetic waves or radio signals through a material is governed by the product of the magnetic permeability of the material and its dielectric constant. For many substances the magnetic permeability is unity. In such cases the travel of waves in the material is dependent only on the complex dielectric constant or the ability of the material to "store" electrical energy. In this connection the Radio and Microwave Materials Section has participated in studies on the dielectric properties of

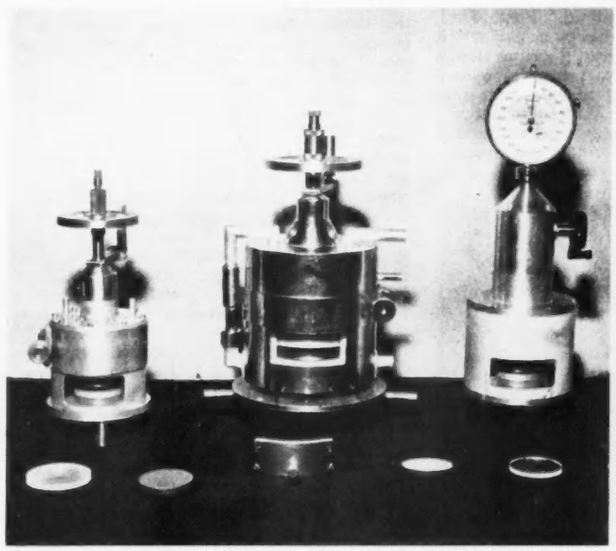


Fig. 3—Electrode systems employed at the N.B.S. in making standard dielectric measurements on solids by bridge and resonance methods

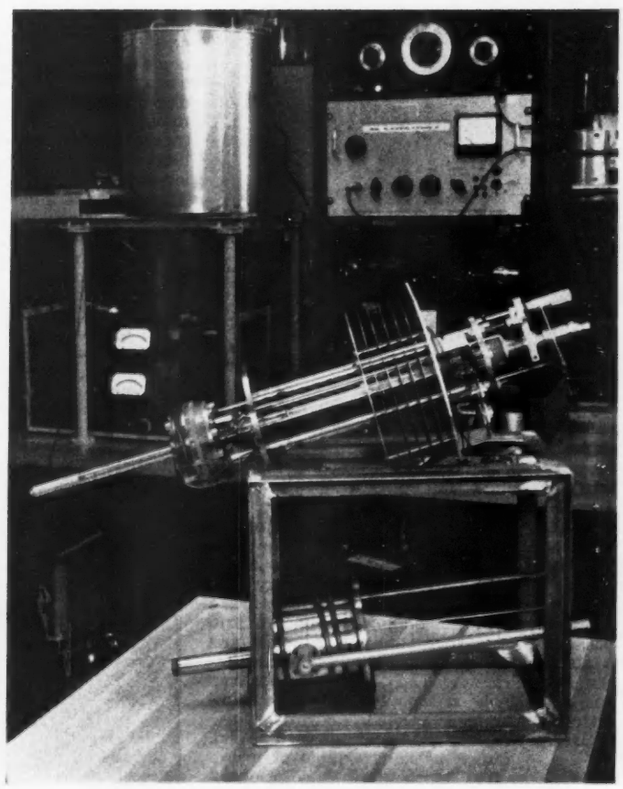


Fig. 4—Disassembled fusion cell, with outer housing at upper left, principal unit in the centre and cell housing at lower right

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BY OUR AMERICAN EDITOR

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During the past few years, demands for dielectric materials designed for specific applications have become more and more insistent. In the missile and aircraft fields, for example, dielectrics with electrical properties that are relatively independent of temperature are needed. To create dielectrics for special purposes in this way, the effects of various physical conditions on electrical properties must be determined, and the relationship between molecular behaviour and electrical properties must also be established. Programmes of dielectric studies, carried out by the Bureau's Dielectrics Section and ferroelectricity group in Washington, and the Radio and Microwave Materials Section of the Boulder Laboratories in Colorado, provide concepts for this work.

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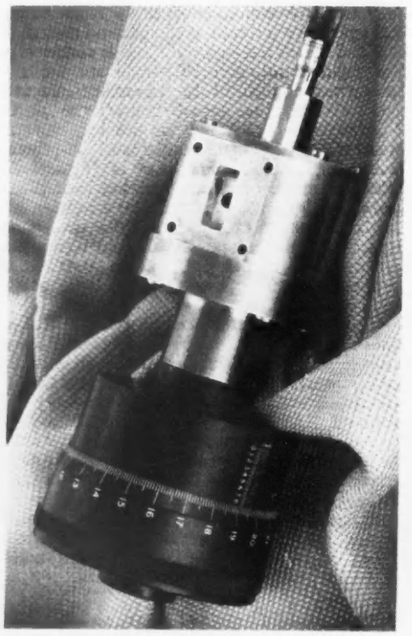

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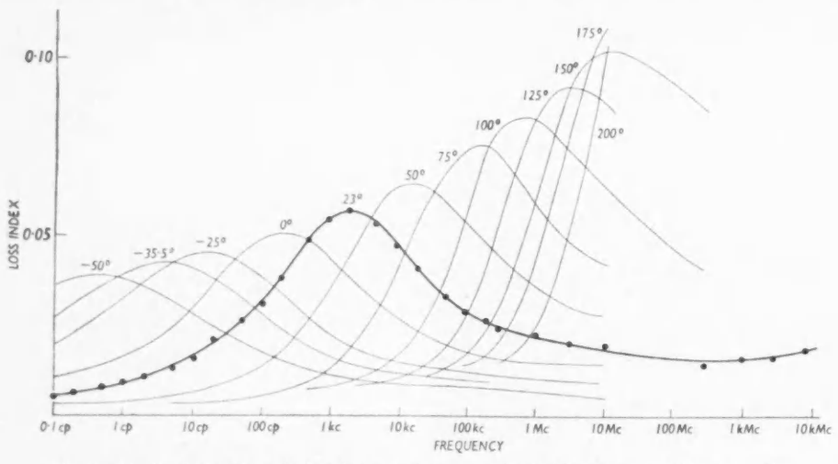

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In the interaction between electromagnetic waves and matter, conductivity properties of materials are essentially inseparable from the dielectric properties. At radio and microwave frequencies conductivity studies are therefore an important component of any dielectrics programme. In this connection, the Radio and Microwave Materials Section is investigating the tensor or directional conductivity of semi-conductors such as single crystals of germanium at microwave frequencies under different physical conditions. Some important questions in the theory of solid state will be investigated in this work. It is expected that these studies will yield a better understanding of the crystal lattice forces and processes. The results may prove of value in microwave engineering if the tensor properties for radio waves are appreciable.

Among other examples of the Bureau's research in dielectrics are refractometer studies. The refractometer determines the dielectric properties of the atmosphere, which in turn determine the propagation characteristics of the troposphere, so important to radar and other means of microwave communication. The Bureau's work constitutes the background for successful applications in this field for military and other purposes. The propagation of electromagnetic waves or radio signals through a material is governed by the product of the magnetic permeability of the material and its dielectric constant. For many substances the magnetic permeability is unity. In such cases the travel of waves in the material is dependent only on the complex dielectric constant or the ability of the material to "store" electrical energy. In this connection the Radio and Microwave Materials Section has participated in studies on the dielectric properties of

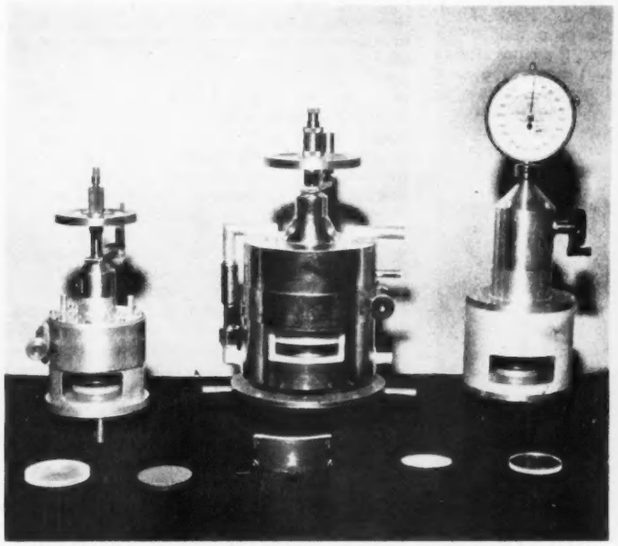


Fig. 3—Electrode systems employed at the N.B.S. in making standard dielectric measurements on solids by bridge and resonance methods

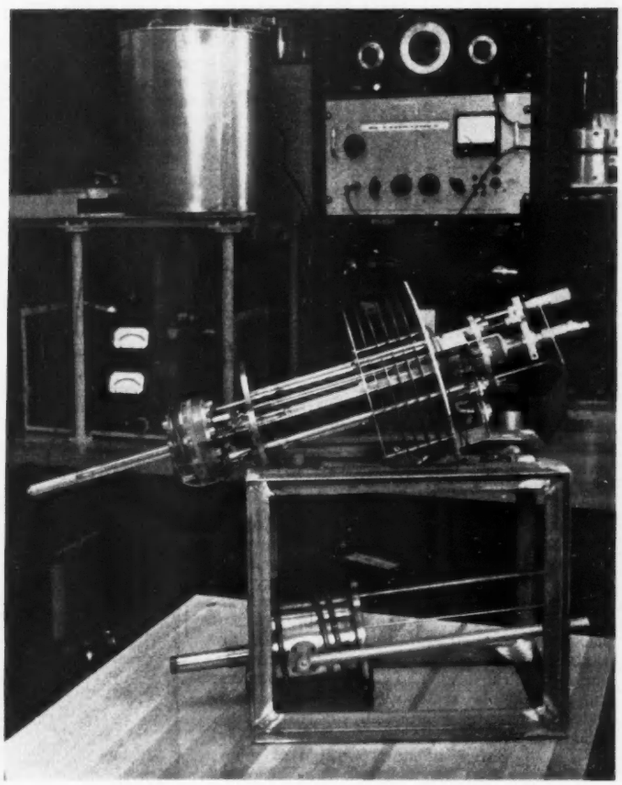


Fig. 4—Disassembled fusion cell, with outer housing at upper left, principal unit in the centre and cell housing at lower right

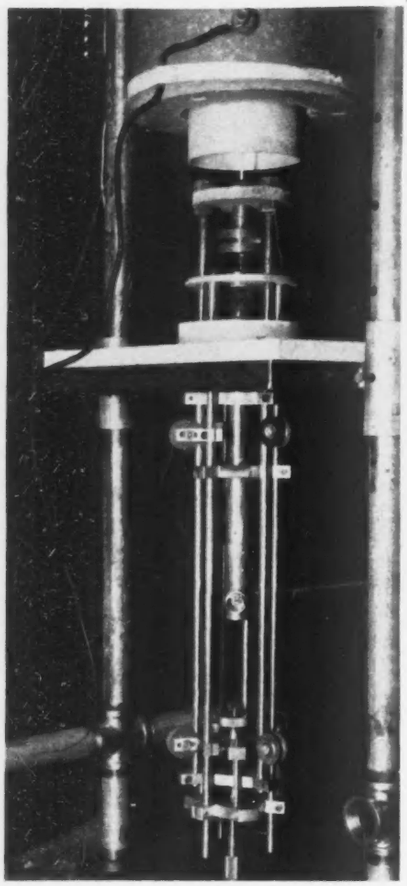


Fig. 5—Stainless steel specimen holder for dielectric measurements at temperatures up to 500 deg. Cent.

various propagation media, such as ferrites, soils, tar sands, and oil-bearing sandstones. Ferrites are magnetic materials that have important magnetic properties at radio and microwave frequencies and have gyrotropic or directional characteristics important in microwave applications. They also have very high dielectric constants which are currently being investigated. Studies on soils are important in placing wireless transmitters and aerials and establishing and predicting wireless communication links. Tar sands and oil-bearing sandstones contain valuable oil deposits which do not flow under their normal temperature environment in which the tar sands and paraffin in oil are solid. By the application of suitable radio or microwave energy it is hoped to tap these resources by warming the deposits sufficiently for flow. Here the properties of composite dielectrics are of particular interest.

Standardising Dielectric Measurements

Accuracy in dielectric measurements is basic to all electrical applications, where dielectrics often set limits on voltage, frequency, absorption, reflection, and temperature of operation. For this reason, the electrical properties of dielectrics must be determined before the materials are incorporated in electrical equipment such as capacitors, transmission lines, aerials, transmitters, transducers and generators. Furthermore, as small changes in production techniques may radically alter the electrical properties of the material, additional measurements are sometimes necessary to control the quality of the finished equipment. The Bureau helps to meet the ever-increasing need for accuracy and reliability by improving measuring techniques and developing reference standards. This work is carried out principally by the Dielectrics Section in the Washington Laboratories and the Radio and Microwave Materials Section in the Boulder Laboratories. The Boulder Laboratories are responsible for dielectric tests and standards at and above 30 kc/s, and the Washington Laboratories are responsible for similar work at lower frequencies. In addition, the results obtained by the Bureau's chemistry laboratories in research on molecular dynamics are frequently applicable to standardisation procedures.

The Bureau calibrates the dielectric properties of transfer standard samples submitted by other laboratories, but would prefer to issue its own standard samples of selected material having known dielectric behaviour as a function of environmental conditions and time. Such reference standards may then be used with confidence by industry and other institutions in calibrating any dielectric measuring system. Careful studies of material for reference standards (Fig. 7) are therefore being conducted in both of the standards laboratories, with support from the chemistry laboratories. Such a standard may be a gas, a liquid, or a solid. Recommended values of the dielectric constants of a selected number of liquids and gases that are useful as standards are therefore included in the Bureau's tabulations of dielectric properties. These tables also provide a concise and, wherever feasible, critically evaluated listing of dielectric data on a wide variety of substances. One table gives the dielectric constants for over 800 organic and inorganic liquids as a function of temperature; another presents the electric dipole moments, derived from microwave spectroscopy and measurements of the dielectric constants, for about 350 gases; and a third lists values of the dielectric constant and dielectric loss index as a function of frequency for about 200 liquids and a number of dilute aqueous and non-aqueous solutions.

Several factors enter into the reliability of a solid as a dielectric standard. First of all, for a material to be suitable as a standard it must be uniform. The Bureau therefore studies the uniformity of dielectric properties over a single specimen by making measurements with different sized electrodes. Uniformity between specimens is, of course, determined by measuring several specimens. Another important consideration in selecting a material as a dielectric standard is the influence of environmental factors on the stability of electrical properties. To determine the effect of one of the most important of these factors—relative humidity—the Bureau measures specimens after they have been kept for several weeks in a desiccator where the relative humidity is less than 1 per cent, and again after they have been kept for several weeks in a relative humidity of 50 per cent. The most promising materials are those whose electrical properties are not greatly affected by the humidity. Humidity studies are presently under way on poly(methyl methacrylate), polystyrene, polyethylene and fused quartz to determine their suitability as dielectric standards. In further efforts to ensure accuracy, the Bureau is co-operating with the American Society for Testing Materials in developing improved techniques for two-terminal measurements and for dielectric measurements of microwave ferrites and ceramics.

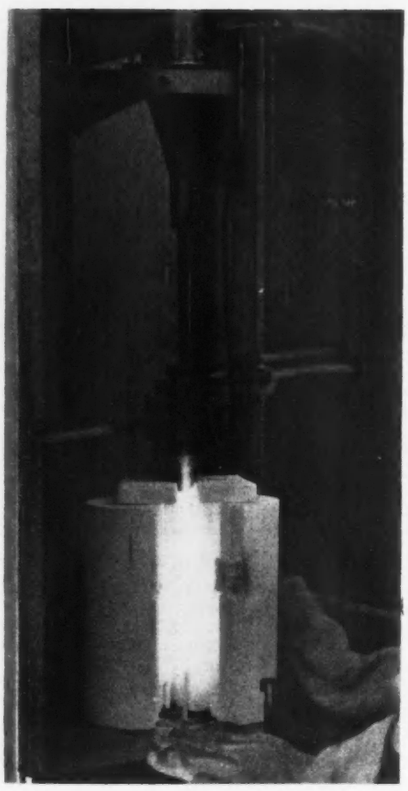
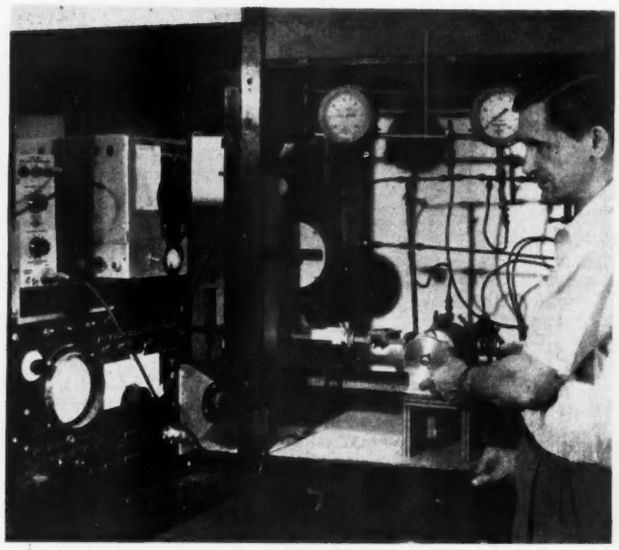


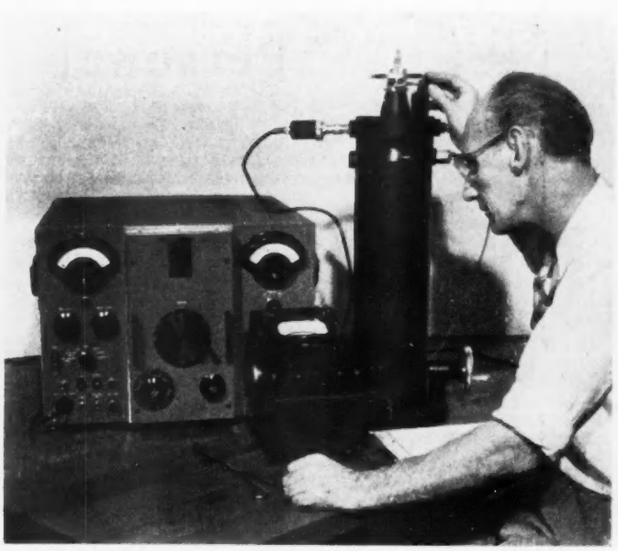
Fig. 6—Growing of single inorganic crystals, with powdered material dropping from above through the flame, melting and forming a crystal on the vertical rod at the furnace base

Fig. 7—Measuring the dimension of a dielectric reference standard by means of a travelling microscope

At microwave frequencies exact solutions for a cavity resonator with a dielectric sample have been developed and "programmed" on the automatic calculator so that the data may be evaluated conveniently (Figs. 8 and 9). Certain errors such as those due to frequency pulling by the coupling devices and the hole for inserting the sample, have been evaluated in this way. An automatic dielectrometer covering a frequency range of 500 kc/s to 800 Mc/s and temperature range from −40 deg. to 350 deg. Cent. is now being developed. Two types of two-terminal measurements are in use; the open-type measurement, where edge and ground capacitance corrections are applied, and the micrometer-electrode holder measurement, which eliminates these corrections. A disadvantage inherent in the latter technique is the requirement that the specimen be a flat plate with sides perpendicular to the surface, and edges which are sharp with no rounding or chipping. The Bureau is presently studying micrometer-electrode holder techniques in an effort to improve this type of measurement. The accuracy of the dielectric constant measurement by this technique is affected by the means used to set the electrodes and to measure the spacing between them, while the accuracy of the dissipation factor measurement is affected by changes in relative humidity. For the measurement of high-loss materials, the loss in the holder is a negligible correction, but for low-loss materials it can be appreciable—in some cases it is of the same order of magnitude as the loss in the specimen.

Accuracy in dielectric measurements at low frequencies is dependent not only on measuring techniques and devices, but ultimately on the accuracy of the National standard of capaci-





Figs. 8 and 9—(Left) Resonant cavity containing a gas sample being tuned in preparation for determining dielectric properties by the microwave absorption technique. (Right) Performance of dielectric measurements by means of a 100 Mc/s to 500 Mc/s re-entrant variable-length cavity resonator

tance as maintained by the Bureau. At present, a new improved absolute standard, developed last year, is coming into use. This standard is accurate to a few parts in a million and was made possible by a special three-winding transformer bridge and a three-terminal assembly whose capacitance depends solely on its length. Although the present status of dielectric measurements and the lack of reproducibility among samples of the same dielectric material do not allow the accuracy of the standard to be fully utilised in dielectric research, the bridge itself is finding immediate use. In a modified form, which will sacrifice some accuracy for a wide frequency range, the transformer bridge will be used to measure dielectric losses.

At radio and microwave frequencies the accuracy of dielectric measurement depends ultimately on the basic radio and microwave standards, which are calculable geometrical structures. A recent development here is the construction of an impedance standard calculated mathematically and measured experimentally with agreement to better than 0·1 per cent. The ability to measure impedance accurately then leads to accurate dielectric measurements. Equally valuable are the exact solutions for cavity geometries with perturbation corrections for all departures from an ideal structure. An example of such a departure is a coupling device or a hole, as mentioned above.

Through this comprehensive programme of dielectric activities, which begins with the development of a primary standard, extends through improved measurements, and results in materials data and an understanding of fundamental behaviour, the Bureau provides the basis for the technological application of dielectric materials. Efforts will continue along the lines described, with emphasis continually shifting toward basic studies as the accuracies necessary for the effective application of data are realised.

Gas-Fired Storage Water Heater

An indirect gas-fired scale-free storage water heater has been developed by the Patterson-Kelley Company, of East Stroudsburg, Pennsylvania. This self-contained unit employs three basic systems. One is the gas-burning system—the furnace part of the unit. Then, there is a forced-circulation transfer fluid system. Finally, in the service water system there are provisions for storage, heating and temperature control. The gas burner is mounted at one end of the heater, and the draught hood for connection to a suitable vent is at the other. The flame and products of combustion pass along inside a horizontal cylindrical tube that goes through the storage section. Although the large fire tube is surrounded by stored service water, the actual working heat-transfer surfaces are on a finned-tube bundle that projects into it from the draught hood end. A separate transfer fluid —usually pure water—circulating through this finned combustion bundle carries the heat to the service water. The nozzle-mixing gas burner is a modified commercial unit with its own motor-driven blower fan and a self-contained air inlet adjustment. The storage water temperature thermostat turns it off and on. The burner mounting is at right angles to the axis of the tank, so that the flame encounters an L-shaped bend before entering the large tube that passes through the tank; this arrangement promotes high turbulence and excellent combustion.

Combustion is essentially complete at the point where the hot gases reach the finned tube bundle. The gases are passed at high velocity along the finned tubes of the combustion bundle. The bundle is baffled and shrouded so that the gases here occupy only the bundle cross section —not the entire large tube cross section. Fins, welded to the tube walls, afford a large enough surface area so as to achieve efficient gas-to-tube heat transfer that balances the tube-to-fluid rate inside. After the combustion gases pass through the bundle, they arrive at the draught hood for venting. The temperatures at the draught hood are in the order of 300 deg. Fah., or about as low as practical for effective venting. The percentages of CO_2 in the flue gas, with proper adjustments, run within a few tenths of 1 per cent of the theoretical maximum for the type of fuel being burned. This indicates that combustion is almost perfectly complete—that all the fuel is being burned instead of being wasted up the flue.

A closed, self-contained loop is formed by the combustion tube bundle, the water heating bundle and their interconnecting piping. There is a packless water-lubricated "Magneflow" circulating pump in this loop. It is designed for continuous operation so that the transfer fluid circulates around the loop continuously. The reason for using a separate transfer fluid is to avoid scaling conditions on the service water side of the heat-transfer surfaces. The transfer fluid does this by delivering its heat at lower temperatures than a flame-to-service-water arrangement would permit. The transfer fluid will usually be water. Another fluid might be substituted, but reasonably mineral-free water does an excellent job. The highest temperature of the transfer fluid when the burner is firing is about 250 deg. Fah. Thus, it is necessary to operate the loop under pressure to prevent boiling. An air-cushioned expansion tank provides automatically for pressurisation. Corrosion problems do not exist in the transfer fluid circuit because no oxygen or other elements are brought into the system. The service water is heated by the water-heating tube bundle, in which the hot transfer fluid is circulating. True storage conditions exist, because the actual service water is stored in the tank. This contrasts with systems that store "prime water" which, in turn, heats service water in heat-transfer coils.

The Patterson-Kelley Company went back to fundamentals in order to develop the scale-free design of the new heater. Harmful scale consists of material that comes into a water heater dissolved in the water supply. This material becomes scale when it can no longer stay dissolved—when it precipitates out of solution and sticks to heat-transfer surfaces. The change that makes this happen is a rise of water temperature. Most substances dissolve more readily in hot water than cold. But a few—notably calcium sulphate and carbonate—cannot stay dissolved in hot water in the same concentrations as in cold. The hottest water inside a water heater, of course, is on the surfaces of the heat-transfer tubes. It is here that the calcium sulphate goes out of solution most rapidly. Scaling starts in any pits or crevices in the metal and thus bonds itself. The scale that is formed hinders the transfer of heat to the service water. And the scale keeps growing thicker as service water continues to bring in more dissolved calcium sulphate to be precipitated by the heat. In the practical water heater design problem this means that the hotter the heat-transfer surfaces, the faster efficiency will deteriorate due to scale build-up. If those surfaces can operate at lower temperatures, though, it may be possible to stay below the point where precipitation and scaling begin.

The main benefit gained by heating a transfer fluid with the flame and hot combustion gases is that the transfer fluid does not bring in scale-producing materials. Therefore its heat-transfer surfaces do not scale. On the service water side of tubes in the water-heating bundle, it would also be possible to run into scaling conditions if too high a temperature were employed in the transfer fluid system. This system, in the range of 250 deg. Fah., however, avoids such difficulties for a wide practical range of calcium sulphate concentrations. Because the service water stratifies and the cool incoming service water is at the bottom of the unit the heating tubes lie in cool water of probably less than 100 deg. Fah. The metal wall temperature on the outside of each tube will average approximately 160 deg. Fah. More than 1300 parts per million of calcium sulphate can be tolerated under these conditions without approaching the solubility limit. Thus, a water supply having calcium sulphate concentrations as high as 1300 parts per million can be handled in the new water heater successfully. Essentially, no scaling will occur, and even at higher concentrations the formation rate will be unusually low.

Personal and Business

Appointments

MR. H. P. FORDER and MR. A. R. HAY have been appointed directors of The United Steel Companies, Ltd.

SIR PHILIP SOUTHWELL has been appointed chairman of the British subsidiary of Brown and Root Inc., of Houston, Texas.

LIEUTENANT-COMMANDER DOUGLAS F. BATTISON, R.N. (Retd.), has been appointed sales manager of Electropol Processing, Ltd.

DR. PETER GROOTENHUIS has been appointed to the readership in mechanical engineering at the Imperial College of Science and Technology.

EDGAR ALLEN AND CO., Ltd., announces that Mr. F. A. Ross, Mr. W. G. A. Jenkins and Mr. J. Higginbotham have been appointed directors.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., announces the appointment of Mr. J. D. Buchan as assistant manager, publicity department.

MR. P. BEYNON has been appointed works manager, operational research and work study at Steel, Peech and Tozer, a branch of The United Steel Companies, Ltd.

WALKER, CROSWELLER AND CO., Ltd., has announced the appointment of Mr. C. F. Taylor as general manager of the Leonard mixing valve division of the company.

MR. J. E. ARMITAGE has been appointed commercial director of Vickers-Armstrongs (Aircraft), Ltd., in succession to Mr. J. Anderson, who has retired on account of continued ill health.

MR. B. BAXTER, M.I.N.A., naval architect at the British Central Office of Bureau Veritas, has been appointed chief representative of Bureau Veritas in the United Kingdom as from December 1.

MR. PETER GREEN has been appointed deputy managing director of Donald Healey Motor Company, Ltd., Healey Car Sales, Ltd., Healey Marine, Ltd., and Healey Automobile Consultants.

PEGSON, Ltd., announces the appointment of Mr. C. E. Hutchinson as home sales manager—mining and quarry plant division. Mr. A. Suttill has been appointed chief sales engineer, export.

QUALCAST, Ltd., announces that Mr. W. H. Barnes, vice-chairman, has resigned from the board owing to advancing years. Mr. J. R. Fleming, joint assistant managing director, has been appointed vice-chairman.

MR. G. B. R. FEILDEN, managing director of Hawker Siddeley Brush Turbine Company, and chairman of National Free Piston Power, Ltd., has been appointed to the board of Hawker Siddeley Industries, Ltd.

THE PLESSEY COMPANY, Ltd., announces the appointment of Mr. R. E. Verguson as commercial manager of a new grouping which includes the sheet metal division and the Amar Tool and Gauge Company, Ltd., with the industrial hydraulics division at Cheyney Manor, Swindon.

NORTHERN ALUMINIUM COMPANY, Ltd., has announced the resignation of Mr. C. P. Paton who is taking up a position with Aluminium Ltd., of Canada. Mr. Taylor Cornelius, who has taken over from Mr. Paton as general works manager, has been elected a director of the company.

MR. E. R. LEWIS, chairman of the Decca Group of Companies, and Group Captain E. Fennessy, managing director of Decca Radar, Ltd., have joined the board of directors of General Precision Systems following the acquisition by Decca Radar, Ltd., of a 25 per cent interest in that company.

INTERNATIONAL HARVESTER COMPANY OF GREAT BRITAIN, Ltd., announces that Mr. John D. Abell, Doncaster works manager, is returning to Canada to take up new duties with International Harvester in Hamilton, Ontario. He has been succeeded as works manager at Doncaster by Mr. Frank J. Zmarzly. Mr. Sven L. Sonander has been appointed works manager at Bradford in succession to Mr. Zmarzly.

UNION CARBIDE, Ltd., alloys division, announces the following executive appointments within its sales organisation: Mr. Colin Dunger, area sales manager, Sheffield, has been appointed assistant sales manager; Mr. William Smith, technical sales representative, Scotland, has been appointed area sales manager, Scotland; Mr. William Paton has transferred from the division's development department and has been appointed area sales manager, Birmingham.

THE MINISTRY OF AVIATION announces that Dr. C. M. Johnson has been appointed director of the Explosives Research and Development Establishment at Waltham Abbey. Mr. W. H. Hill has been appointed deputy director of Air Armament Research.

Business Announcements

BROOM AND WADE, Ltd., High Wycombe, has established in Belgium a subsidiary company, Broomwade-Belge S.A.

KEITH BLACKMAN, Ltd., states that with effect from December 4 its Birmingham office will be operating from 1651, Pershore Road, Birmingham, 30 (telephone Kings Norton 4151-2).

COURTAULDS, Ltd., 16, St. Martins-le-Grand, London, E.C.1, is to re-open part of Aber Works, Flint, for the manufacture of bleached sulphate pulp for the paper and board industries.

ECONOMIC FOUNDATIONS, Ltd., 161, Victoria Street, London, S.W.1, has acquired British rights in the Hochstrasser Weise system of making cylindrical concrete foundations by means of an oscillating steel tube.

W. H. ALLEN SONS AND CO., Ltd., announces that Mr. J. C. C. Whyte has been appointed manager of the company's new central counties branch office at Lloyd's Bank Chambers, 85, Regent Street, Leamington Spa.

THE CONSOLIDATED PNEUMATIC TOOL COMPANY, Ltd., announces the opening, on December 1, of a new district office at 1, Bedminster Down Road, Bristol, 3 (telephone Bristol 63736). The office will be under the management of Mr. J. D. Glover.

BRITISH BOILER ACCESSORIES, Ltd., 62-63, Fenchurch Street, London, E.C.3, has entered into an arrangement with the Toronto Iron Works, Ltd., Toronto, Canada, for the sale of B.P.A. steam accumulators and helical coil heat exchangers in Canada.

A.E.I. LAMP AND LIGHTING COMPANY, Ltd., 44, Fitzroy Road, London, N.W.1, has been appointed official lighting consultant for Isora ceilings, which are being marketed in the United Kingdom by S.F.I.M. (Great Britain), 220, Bedford Avenue, Slough, Bucks.

MR. A. S. D. BARRATT, technical director of Edwards High Vacuum, Ltd., is resigning from the board of the company at the end of the year to become an independent consultant. His association with the company is being maintained by his appointment as technical consultant.

LANG PNEUMATIC, Ltd., Owen Road, Wolverhampton, states that Telex has been installed in its head office and at its London office at 69, New Cavendish Street, W.1. The numbers are Telex Wolverhampton 33193 and Telex London 23128. The company has also opened a branch office at 107, Pinstone Street, Sheffield, 1 (telephone Sheffield 27865).

S. SMITH AND SONS (ENGLAND), Ltd., Cricklewood Works, London, N.W.2, states that as a result of an agreement with the Torrington Manufacturing Company, of Torrington, Connecticut, U.S.A., a newly-formed department of the Smiths organisation will manufacture Torrington air impellers and market them throughout the world, with the exception of the Americas. Mr. J. S. Ward has been appointed sales manager of the new department.

Contracts

STENNERS OF TIVERTON, Ltd., has received from the Polish Government an order for a high-speed log bandmill and band push bench. The total value of the contract is in the region of £12,000.

FERRANTI, Ltd., has received orders for two general-purpose Pegasus electronic computers. The first will be installed at the Road Research Laboratory of the Department of Scientific and Industrial Research where it will be used for all aspects of road research calculations, in particular, problems associated with road traffic and safety. The second Pegasus has been ordered by The Steel Company of Wales, and is intended primarily for research studies.

BOULTON AND PAUL, Ltd., of Norwich, has secured a contract valued at £106,000 for the supply of an automatic fabrication plant for structural steelwork from Judson Pacific Murphy of San Francisco. The plant comprises an automatic sawing plant, multi-spindle horizontal and vertical drilling machines, feed and storage benches and control consoles. It is one of an improved and restyled version of the prototype installed at Riverside Works, Norwich, in 1952, and described in our issue of June 19, 1953.

Miscellanea

MOISTURE CONTROL.—The Mobil Oil Company, Ltd., announces the introduction of two new products, namely, Mobil "Sorbead" R and W which have been formulated to effect moisture control. Both have special bead structure considered to confer certain advantages over conventional desiccants particularly in dynamic dehumidification systems. Mobil "Sorbead" R is designed for general use while Mobil "Sorbead" W has been developed as a specially resistant bead for use where liquid water is present.

NAVAL ARCHITECTURE SCHOLARSHIPS.—The Institution of Naval Architects announces the following scholarship awards: The Froude Research Scholarship in Naval Architecture to Mr. J. F. Wellicome, B.Sc., and the Sir William White Post-Graduate Scholarship in Naval Architecture to Mr. F. Taylor, B.Sc., both of King's College, Newcastle upon Tyne; and the Aluminium Development Association Research Scholarship on the Application of Light Alloys to Ship Construction to Mr. C. S. Smith, B.Sc., of the University of Glasgow.

WELDED TROLLEY CONTAINERS.—Trolley containers for handling all types of products, including powders, liquids and semi-liquids, are now made by Light Alloy Construction, Ltd., Mowden Hall, Darlington, Co. Durham. These containers are fabricated from aluminium alloy which is heat treated after forming, to impart a tough, hard surface that is clean to handle and can be sterilised under high temperatures without harm. They are mounted on a strong, lightweight chassis fitted with tapered bearing castors. A draining tap fitted in the base facilitates emptying and cleaning out of containers when necessary.

GERMANIUM SWITCHING TRANSISTORS.—Collector currents up to 6A at 60V can be controlled by a new series of n-p-n germanium alloy transistors developed by Sylvania-Thorn Colour Television Laboratories, Ltd., Great Cambridge Road, Enfield, Middlesex. Among other applications, this GT422 series can be used in conjunction with p-n-p transistors to form complementary pairs for transformerless radio or servo-amplifier output stages, or as series voltage regulators. Other transistors in the same series have ratings of 60V, 3A; 36V, 6A, and 36V, 3A. Maximum junction temperature is 85 deg. Cent.

DOUBLE-ACTING FLUID SEAL.—A double-acting fluid seal for hydraulic pistons introduced by Hall and Hall, Ltd., Oldfield Works, Hampton, Middlesex, comprises two impregnated fabric U-seals bonded to a rubber core. In introducing this seal the makers point out that in conventional practice in sealing double-action mechanisms, when two seals are used back to back, a difficulty arises of dealing with fluid accumulations in the space between these seals. The pocket of fluid thus formed can cause rapid wear of the seals if it is allowed to remain. The new double-acting seal can be mounted centrally in a groove on the piston spigot, filling the diametral clearance between spigot and cylinder.

MINIATURE VALVE FOR COMPUTERS.—A medium-μ miniature twin triode with nine-pin base has been designed by R.C.A. Great Britain, Ltd., Lincoln Way, Windmill Road, Sunbury-on-Thames, Middlesex, for use in pulse-amplifier, inverter, frequency-divider, cathode follower, and multi-vibrator circuits of electronic computers, particularly high-speed digital instruments, and in other equipment using such circuits. The maker states that this valve, designated "7044," maintains its emission capabilities even after long periods of operation under cut-off conditions, and so consistent values of plate current are maintained during its "on" periods. The "7044" has separate terminals for each cathode to allow flexibility in circuit arrangement, and a mid-tapped heater to permit operation from a 6·3V or 12·6V supply.

UNIT HEATERS.—A unit heater known as the "Thermolier" is now being made by Mather and Platt, Ltd., Manchester, in five sizes and operates on steam, low-pressure or high-pressure hot water. The units made cover a thermal output range of between 35,000 and 350,000 B.Th.U. per hour, and it is stated that almost any required output in this range is possible. A thermostat can be fitted into the motor circuit if required, and the louvres of each unit are individually adjustable to control the direction of the warm air stream. In the design of these units, close attention has been paid to the necessity for quiet operation and anti-vibration mountings are fitted to reduce noise to a minimum. The fan has been designed to match the heat exchanger so that the quantity and velocity of air give the maximum thermal efficiency.

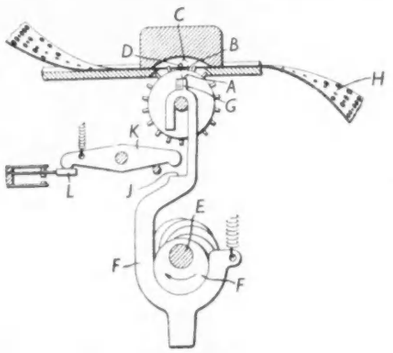
British Patent Specifications

When an abridgment is not illustrated the specification is without drawings, unless otherwise stated. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each.

TELECOMMUNICATIONS

822,785. November 30, 1956.—PERFORATED TAPE READER, Ing. C. Olivetti and Co., Società per Azioni, Ivrea, Italy.

Certain high-speed tape readers possess the inherent disadvantage that the tape is subjected to a major fatigue and that the sensing pins upon withdrawing from the tape are suddenly restored by their springs, thus causing undesirable rebounds. It is an object of the invention to provide a high-speed tape reader which obviates these and other disadvantages. According to the invention, the tape reader comprises a set of spring-actuated sensing pins which are movable perpendicular to the tape for sensing the code combinations perforated therein and which may travel to a limited extent with the tape. The transmitter operates as follows. Upon rotation of the cam shaft *E*, each eccentric drives the corresponding sensing lever *F* through a path defining a closed



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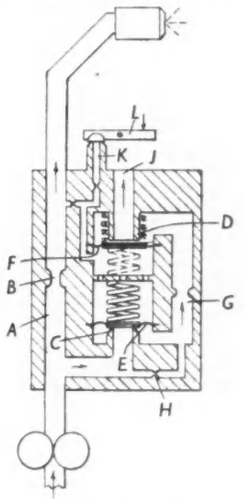
geometrical figure which is substantially an ellipse. This elliptical figure is defined by the letters *A*, *B*, *C*, *D* for the top of the sensing pin *G*. It will be apparent that the top first moves upwards from *A* to *C*, passing through *B*. At *B* the sensing pin enters the hole assumed to be provided in the tape *H* and then moves to *C* substantially concurrently with the tape, which is advanced at the same rate. From *C* the sensing pin returns down to *A*, passing through *D*, where it is withdrawn from the hole. If, however, there is no hole provided in front of the sensing pin, the latter, when at *B*, instead of following the elliptical path *B*, *C*, *D*, will move straight along the horizontal segment *B*—*D* and then return down to *A*. The abutment *J* of the sensing lever contacts the lever *K* when the top of the sensing pin reaches the point *B*. Therefore, if at this instant the sensing pin finds a hole in the tape, enabling the sensing lever further to move upwards, the lever *K* will be rocked, thus operating the contact *L*. If, on the contrary, the sensing pin is prevented by the tape from further moving upwards, the abutment will ride horizontally without causing the lever to be rocked, whereby the contact *L* will not be operated.—*October* 28, 1959.

GAS TURBINES

821,285. March 21, 1957.—CONTROLLING THE SUPPLY OF LIQUID FUEL TO A GAS TURBINE, Joseph Lucas (Industries), Ltd., Great King Street, Birmingham, 19. (*Inventor: Eugene Harold Warne.*)

This invention has for its primary object to enable fuel to be supplied to a gas turbine, when starting, at a rate in excess of what would be the normal maximum turbine speed. Referring to the drawing, there is provided in a body a passage *A* by which the fuel is conveyed from a pump to the burner in the combustion chamber of the turbine. In the passage is a constriction *B* for setting up in the fuel stream a pressure difference. A valve chamber in the body has at one end a by-pass fuel inlet seating *C* and at the other end a by-pass fuel outlet seating *D*. The chamber is divided into three compartments by a pair of flexible spring-loaded diaphragms *E* and *F*. The two ends of the chamber are interconnected by a by-pass *G* provided with a constriction. The entrance end of the by-pass and also the entrance to the adjacent seating are preferably interconnected by a branch passage with a constriction *H*. The compartment between the diaphragms is connected to the downstream side of the constriction *B* in the fuel passage by a branch passage which may contain a constriction. On starting of the turbine, the rate of discharge of the pump (which is driven by the turbine) is sufficient to supply fuel to the combustion chamber at a rate in excess of the normal maximum rate which would be required at the particular speed when the turbine is working normally, but while starting the fuel pressure difference at opposite sides of the constriction *B* is inadequate to effect opening of the closure member of diaphragm *H*. After ignition, the turbine, commences to work under its own power and, while accelerating, the pressure difference in the fuel passage *A* rises suffi-



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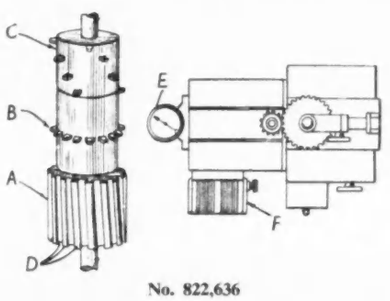
ciently to effect opening movement of *H*. In this condition a part of the fuel supplied by the pump is diverted through the by-pass *G* and the closure member of diaphragm *D* will then adjust itself so that the amount of fuel diverted through the outlet passage *J* to a sump or the inlet side of the pump is determined by the ratio of the areas of the constrictions in the fuel passage and by-pass, and also by the spring-loading on diaphragm *D*. The amount of fuel which then passes to the turbine is at the normal maximum rate which would be required to meet the demand of the turbine at the particular speed concerned.

Regulation of the rate of supply of fuel to the turbine during normal working conditions may be effected in any convenient manner, such as by the action of a speed governor. For this purpose there may, for example, be provided in the body a vent passage *K* having a restriction and terminating in a seating which is normally closed by a lever *L* operated by a governor or other means. Opening of the vent results in reduction of the fuel pressure acting on the underside of the diaphragm *F*, so enabling the extent of opening to be increased by the pressure of the by-pass fuel acting on the upper side of this diaphragm.—*October* 7, 1959.

GEAR INSPECTION EQUIPMENT

822,636. December 7, 1956.—MASTER GEARS, Illinois Tool Works, Chicago, Illinois, United States of America. (*Inventor: Henry Pomernacki.*)

An object of the invention is to provide a device whereby individual characteristics of a gear wheel such as lead, tooth profile and helix may be separately checked rapidly and economically. Another object is to provide a master gear wheel which may be used on a conventional gear wheel checking apparatus in place of master gear wheels. The accompanying drawings show one example of a



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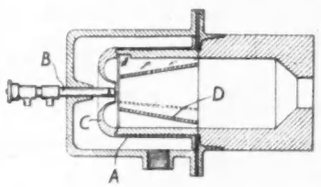
master gear wheel adapted to be used with a conventional gear wheel checking apparatus shown on its right. The master gear wheel has sections *A*, *B* and *C*, each with different types of teeth for checking different characteristics of a workpiece gear tooth. The workpiece is selectively positioned for engagement with the teeth on one of the master gear wheel sections by shifting the workpiece gear wheel along its support mandrel and this may be accomplished by using one or more spacing blocks. The section *A* of the master gear wheel is provided with helical tooth elements *D* equally spaced around the wheel for checking the off-lead condition of a helical workpiece gear wheel. As will be understood, carry-over, i.e. the simultaneous engagement of two pairs of teeth in helical gears, is obtained not only from the tooth form but also from the helix. Thus, in order to check the helix or off-lead condition of a workpiece, the tooth elements *D* are formed with substantially no involute or other conventional tooth profile, so that when the section *A* is rolled with a workpiece, substantially only helical carry-over is obtained and the off-lead condition will be indicated by the dial *E* or on the recording mechanism *F*. The master gear wheel section *B* is provided with tooth elements which are formed so as to substantially eliminate the helical carry-over and to check only the profiles of the workpiece gear wheel teeth. These tooth elements have narrow band-like workpiece-engaging surfaces formed so as to check the full depth of the workpiece teeth. The master gear wheel section *C* has narrow tooth elements so formed and arranged that any tapering of off-parallel condition of the teeth along the axis of the workpiece will cause a displacement of the master gear wheel from the position a conventional composite check master gear wheel would occupy, and the amount of this displacement indicates the condition of the gear helix. This gear section *C* is particularly useful for checking the gear helix of workpieces having low helix angles and may also be used for checking the parallel relationship of spur gear teeth. In addition, a fourth section may be provided for the master gear wheel, having conventional teeth for obtaining a composite check of the workpiece.—*October* 28, 1959.

LIQUID FUEL BURNERS

822,776. August 1, 1957.—LIQUID FUEL BURNERS, Heurtey et Cie, 38, Avenue George Mandel, Paris (Seine), France.

The drawing shows a cross section of a burner according to this invention. The burner as shown comprises a bell-shaped casing fixed to the combustion chamber. The housing contains a cylindrical shell *A* with a refractory lining. The refractory lining towards the injector *B* has a semi-toroidal deflector *C* having a thick outer lip and a thin inner



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lip. The thin lip extends around the nose of the injector with a clearance for the passage of combustion air. The refractory lining supports through radial webs the frusto-conical body *D* of a vaporisation chamber of a refractory material; the smaller end of the chamber has a diameter greater than the limiting diameter of the thin lip of the deflector, and the diameter of the larger end is less than that of the combustion chamber. The apertures which surround the larger end of the vaporisation chamber draw from the combustion chamber in a zone of combustion gases which are re-cycled by induction to the periphery of the thin lip, upstream of the vaporisation chamber these active products producing pronounced heating of the wall *D*. The shape of the wall *D* eliminates an impact surface for the droplets of atomisation so that the formation of a solid deposit is avoided. This form is such that it conforms approximately to the lateral surface presented by the cone of atomisation, but is spaced from it.—*October* 28, 1959.

METALLURGY

822,774. July 22, 1957.—MEASURING BATH TEMPERATURE IN THE BLOWING PROCESS FOR THE CONVERSION OF STEEL, Hüttenwerk Oberhausen Aktiengesellschaft, 66, Essener Strasse, Oberhausen/Rheinland, Germany.

With the ever-increasing demand for better quality steels, the problem of controlling the bath by measuring the temperature in the blowing process in a converter has assumed increased importance, since

the level and progress of the temperature of the molten metal are closely related to the course of the metallurgical processes. The object of the invention is to provide for the measuring of the temperature in a manner that is more accurate than is possible by the radiation measurement method. According to the invention, a method of measuring the bath temperature in the blowing process for the conversion of steel comprises extracting dust from the converter gases, and analysing the dust quantitatively as to at least one of its essential alkali constituents, CaO, Na_2O, or K_2O, and converting the value thus ascertained into terms of bath temperature. It is based on the fact that the alkali constituents of the dust originate as vapour from the slag, since there are no alkalis in the metallic portion.—*October* 28, 1959.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

To-day, Nov. 27.—STOKE AND CREWE BRANCH: Grand Hotel, Hanley, "Protective Equipment for Industrial Plant," W. L. Stern, 7.30 p.m.

Sat., Nov. 28.—ESSEX BRANCH: Visit to Park Royal Brewery of Arthur Guinness, Son and Co., Ltd., 10.30 a.m.

Mon., Nov. 30.—ALDERSHOT AND DISTRICTS BRANCH: Prince of Wales Hotel, Woodbridge Road, Guildford, "Temperature Control," J. A. Taylor, 7.30 p.m.

Tues., Dec. 1.—NEWCASTLE UPON TYNE AND DISTRICT BRANCH: Crown Hotel, Clayton Street, Newcastle upon Tyne, "Space Travel," 7.30 p.m. ★ NOTTINGHAM BRANCH: Westcotes Constitutional Club, Leicester, Film evening, 7.30 p.m. ★ READING AND DISTRICTS BRANCH: "Marquis of Lorne," Friar Street, Reading, "Life as an Airline Pilot," M. C. L. Carter, 7 p.m. ★ WEST KENT BRANCH: George and Dragon, Ightham, Film, "Electrical Shop Window of 1959," 7.30 p.m. ★ WEST LONDON BRANCH: Windsor Castle Hotel, 134, King Street, London, W.6, "Electric Clocks," D. Burgess, 7.30 p.m.

Wed., Dec. 2.—HALIFAX BRANCH: Crown Hotel, Horton Street, Halifax, "Telecommunications in the Modern Age," L. F. Reynolds, 7.45 p.m. ★ NORTH LONDON BRANCH: Wood Green Civic Centre, Town Hall, London, N.22, "Protective Equipment for Industrial Plant," W. L. Stern, 8 p.m. ★ PRESTON BRANCH: R.A.F.A. Club, East View, Preston, "Control Centres for Modern Industry," K. W. Liller, 7.30 p.m.

Fri., Dec. 4.—LIVERPOOL AND DISTRICT BRANCH: Industrial Development Centre, Paradise Street, Liverpool, 1, "Fire Protection," J. R. Moyle, 7.30 p.m.

BRITISH COMPUTER SOCIETY

Tues., Dec. 1.—MANCHESTER BRANCH: Manchester College of Science and Technology, Sackville Street, Manchester, "A Large Data Processing System," W. E. Scott, 7 p.m. ★ NEWCASTLE BRANCH: University Computing Laboratory, 1, Kensington Terrace, Newcastle upon Tyne, "Linear Programming and its Applications," A. Muir, 7 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

To-day, Nov. 27.—SOUTH MIDLANDS SECTION: North Gloucestershire Technical College, Cheltenham, "A Vidicon Television Camera Channel," B. J. Pover, 7 p.m.

Wed., Dec. 2.—LONDON BRANCH: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, Annual General Meeting, 6 p.m.; Address by the President, E. E. Zepler, 7.15 p.m. ★ SOUTH WALES SECTION: Glamorgan College of Technology, Treforest, Chairman's Address, "Wastage in Technical Education," J. Cotterell, 6.30 p.m.

COMBUSTION ENGINEERING ASSOCIATION

Wed., Dec. 9.—NORTHERN REGION: Great Northern Hotel, Leeds, Discussion on "The Clean Air Act," 2.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Mon., Nov. 30.—BIRMINGHAM CENTRE: Regent House, St. Philip's Place, Colmore Row, Birmingham, "The Association of Light and Colour," A. D. Charters, 6 p.m.

Tues., Dec. 1.—HULL CENTRE: Lecture Theatre, Yorkshire Electricity Board, Ferensway, Hull, "Fifty Years of Lighting Development," J. W. Powell, 6.30 p.m.

Wed., Dec. 2.—EDINBURGH CENTRE: Y.M.C.A. Social Room, 14, South St. Andrew Street, Edinburgh, "New Data for Calculation of Coefficients of Utilisation," W. Robinson, 6.15 p.m. ★ NEWCASTLE UPON TYNE CENTRE: Room B7, Percy Buildings, King's College, Queen Victoria Road, Newcastle upon Tyne, 1, Symposium of "Present Day Commercial Lighting," 6.15 p.m.

Thurs., Dec. 3.—GLASGOW CENTRE: British Lighting Council, 29, St. Vincent Place, Glasgow, C.1, "New Data for Calculation of Coefficients of Utilisation," W. Robinson, 6.30 p.m.

Mon., Dec. 7.—LEEDS CENTRE: British Lighting Council, 24, Aire Street, Leeds, 1, "The Next Fifty Years of Lighting Development," R. T. O. Freeth, 6.15 p.m.

INSTITUTE OF MARINE ENGINEERS

To-day, Nov. 27.—NORTHERN IRELAND PANEL: Central Hall, College of Technology, Belfast, "Reactor Design, Particularly of Types Suitable for Marine Propulsion," E. Long, 7.30 p.m.

INSTITUTE OF PETROLEUM

Wed., Dec. 2.—61, New Cavendish Street, London, S.W.1, "Potentialities of Urea in Dewaxing Middle and Heavy Distillates," J. Marechal and P. de Radzitzky, 5.30 p.m.

Fri., Dec. 4.—Shell-Mex House, Strand, London, W.C.2, Film Evening, 6 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Tues., Dec. 1.—EASTERN CENTRE: Golden Hind Hotel, Cambridge, three papers by members, 7 p.m.

Wed., Dec. 2.—EAST MIDLANDS CENTRE: Mechanics' Institute, Nottingham, "The Design of Radial-Flow Turbo-chargers," E. Kellett, 7.30 p.m.

Mon., Dec. 7.—EAST REGIONAL CENTRE: Council Chamber, Houldsworth Hall, 90, Deansgate, Manchester, "Taking Stock on Maintenance," P. H. Wyke Smith, 7.30 p.m. ★ WEST REGIONAL CENTRE: Liverpool Architectural Society's Rooms, Bluecoat Chambers, School Lane, Liverpool, 1, "The Use of Plastics in Road Transport," J. Langford-Allen, 7.30 p.m.

INSTITUTE OF SHEET METAL ENGINEERING

Tues., Dec. 1.—SOUTH-WEST BRANCH: Department of Engineering, The University, Bristol, "Plastic Tooling," 7 p.m.

INSTITUTE OF WELDING

Fri., Dec. 4.—54, Princes Gate, London, S.W.7, Conversazione, "I.I.W. Work in Hand," 4 p.m.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Mon., Nov. 30.—WEST MIDLANDS CENTRE: Room No. 118, Gosta Green Technical College, Birmingham, "The Latest Developments in Metallurgy with Possible Agricultural Engineering Uses," J. Williams, 7.30 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Wed., Dec. 2.—MIDLANDS BRANCH: Midland Hotel, Birmingham, "Sieve Tray Performance at Reduced Pressure," S. R. M. Ellis, P. E. Barker and R. N. Contractor, 6.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Dec. 1.—Great George Street, London, S.W.1, "The Economic Assessment of Returns from Road Works," G. Charlesworth and J. L. Paisley, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Tues., Dec. 1.—MEASUREMENT AND ELECTRONICS SECTIONS: Savoy Place, London, W.C.2, "Frequency Variations of Quartz Oscillators and the Earth's Rotation in Terms of the N.P.L. Caesium Standard," L. Essen, J. V. L. Parry and J. McA. Steele, 5.30 p.m. ★ SHEFFIELD SUB-CENTRE: City Hall, Sheffield, Faraday Lecture, "Electrical Machines," M. G. Say, 7.30 p.m. ★ SOUTH-EAST SCOTLAND SUB-CENTRE: Carlton Hotel, North Bridge, Edinburgh, "Future Generation and Transmission Development in Scotland, J. Henderson, 7 p.m.

Wed., Dec. 2.—TEES-SIDE SUB-CENTRE: Cleveland Scientific and Technical Institution, Middlesbrough, "Subscriber Trunk Dialling," D. A. Barron, 6.30 p.m. ★ NORTH MIDLAND EDUCATION DISCUSSION CIRCLE: Electrical Engineering Dept., Lecture Theatre, The University, Leeds, Discussion on "The Teaching Approach to the Part III Candidate," opened by E. C. Walton, 6.30 p.m. ★ SOUTH-WEST SCOTLAND SUB-CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, "Future Generation and Transmission Development in Scotland," J. Henderson, 6 p.m. ★ RUGBY SUB-CENTRE: College of Technology and Arts, Rugby, "A System for the Automatic Recognition of Patterns," R. L. Grimsdale, 6.30 p.m. ★ SOUTHERN CENTRE: South Eastern Electricity Board Offices, Hove, "The Provision of Adequate Electrical Installations in Buildings": (*a*) "Houses," C. C. Hyams, and (*b*) "Multi-Storey Flats and Maisonettes," C. A. Belcher, 6.30 p.m.

Thurs., Dec. 3.—ORDINARY MEETING: Savoy Place, London, W.C.2, "The Transmission of News Film over the Transatlantic Cable," C. B. B. Wood and I. J. Shelley, 5.30 p.m. ★ EAST MIDLAND CENTRE: Albert Hall, Nottingham, Faraday Lecture, "Electrical Machines," M. G. Say, 7 p.m.

Fri., Dec. 4.—MEDICAL ELECTRONICS DISCUSSION GROUP: Savoy Place, London, W.C.2, Discussion on "Nuclear Magnetic Resonance," opened by N. Sheppard and R. E. Richards, 6 p.m. ★ SOUTH MIDLAND CENTRE: Midland Institute, Birmingham, Joint Meeting with the Midland Branches of the Institution of Civil Engineers and the Institution of Mechanical Engineers, "The Jodrell Bank Radio Telescope," H. C. Husband, 6 p.m.

Mon., Dec. 7.—ELECTRONICS AND COMMUNICATIONS SECTION: Savoy Place, London, W.C.2, "Frequency Patterns for Multiple-Radio-Channel Routes," B. B. Jacobsen, 5.30 p.m. ★ EAST ANGLIAN SUB-CENTRE: Technical College, Cambridge, "Rockets and Satellites," R. L. F. Boyd, 6.30 p.m. ★ MERSEY AND NORTH WALES CENTRE: Royal Institution, Colquitt Street, Liverpool, "The Deltic Locomotive," C. M. Cock, 6.30 p.m. ★ NORTH-EASTERN MEASUREMENT AND ELECTRONICS GROUP: Rutherford College of Technology, Newcastle upon Tyne, 1, "Dielectric Materials—Trends and Prospects," C. G. Garton, 6.15 p.m. ★ SOUTH MIDLAND CENTRE: College of Technology, Birmingham, Joint Meeting with the Electronics and Measurement and Supply and Utilization Groups, "Some Industrial Applications of Electro Heat," E. May, 6 p.m. ★ WESTERN CENTRE: Technical College, Gloucester, "The Influence of Consumers' Load Consumption Characteristics on Metering Practice," L. B. S. Golds, 6 p.m.

INSTITUTION OF ENGINEERING DESIGNERS

Wed., Dec. 2.—MIDLANDS BRANCH: Queens Hotel, Birmingham, "Diesel Engine Design Problems," H. Haith; and "The Manufacture and Design of Cold Rolled Sections," C. Green, 7 p.m.

INSTITUTION OF HIGHWAY ENGINEERS

Thurs., Dec. 3.—YORKSHIRE AND LINCOLNSHIRE BRANCH: Griffin Hotel, Leeds, "Highway Lighting," G. Berry, 7 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

Tues., Dec. 1.—AUTOMOBILE DIVISION: 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "Is High-Compression Ratio Worth Pursuing?" 6 p.m. ★ SOUTHERN GRADUATES' SECTION: Grand Hotel, Bournemouth, "Gas Lubricated Bearings," G. W. K. Ford, 7.30 p.m.

Wed., Dec. 2.—ORDINARY MEETING IN CONJUNCTION WITH THE HYDRAULICS GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, "Sealing Characteristics of Stuffing-Box Seals for Rotating Shafts," D. F. Denny and D. E. Turnbull, 6 p.m. ★ S. WALES GRADUATES' SECTION: Kings Head Hotel, Newport, Monmouth, Informal Discussion Evening, 7 p.m.

Thurs., Dec. 3.—EASTERN BRANCH: Assembly House, Norwich, "Recent Developments in Lightweight High Output Air and Liquid Cooled Diesel Engines," G. W. Bone and W. R. Dingle, 7.30 p.m. ★ N.W. BRANCH: Engineers' Club, Albert Square, Manchester, "Mechanical Problems of the Electrical Engineer," F. W. Consterdine, 6.45 p.m. ★ YORKSHIRE GRADUATES SECTION: Grand Hotel, Sheffield, "Heavy Machining Operations," K. Woodcock, 6.30 p.m.

Fri., Dec. 4.—MIDLAND BRANCH: Midland Institute, Birmingham, "Jodrell Bank Radiotelescope," H. C. Husband, Film, "The Inquiring Giant." ★ E. MIDLANDS GRADUATES' SECTION: Visit to Stanton Ironworks Company, Ltd., Near Nottingham, 7.15 p.m.

Mon., Dec. 7.—Rolls-Royce Welfare Hall, Derby, "Mechanical Design Aspects of the 'Comet' Engine," F. R. Morley, 6.15 p.m.

INSTITUTION OF NAVAL ARCHITECTS

Thurs., Dec. 3.—10, Upper Belgrave Street, London, S.W.1, "New Sea Trials on the Sand-Blasted Lubumbashi," G. Aertssen, 4.45 p.m.

INSTITUTION OF PLANT ENGINEERS

To-day, Nov. 27.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, "Instrumentation in Industry with Particular Reference to Control of Temperature, Pressure Flow, Weight, &c.," L. F. Cohen, 7.30 p.m.

Tues., Dec. 1.—EDINBURGH BRANCH: "Wee Windaes," High Street, Edinburgh, Informal Discussions, 7 p.m. ★ PETERBOROUGH BRANCH: White Lion Hotel, Church Street, Peterborough, "Automatic Control Using Computers for Machine Tools," M. Monk, 7.30 p.m.

Wed., Dec. 2.—SOUTHERN BRANCH: Wm. R. Selwood, Ltd., Plant Depot, Chandler's Ford, Practical Demonstration of Low Temperature Welding Methods, 7 p.m.

Thurs., Dec. 3.—LONDON BRANCH: Royal Institution, 21, Albemarle Street, W.1, "An Introduction to Electronic Data Processing," H. A. Thomas, 7 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, Nov. 27.—WALES REGION: South Wales Institute of Engineers, Park Place, Cardiff, "Photography in Engineering," P. H. Herbert, 7 p.m.

Tues., Dec. 1.—LEICESTER SECTION: Grand Hotel, Leicester, "Industrial Engineering—Its Scope and Opportunities," J. E. Faraday, 7.15 p.m. ★ PETERBOROUGH SECTION: Conference Room, Peterscourt, Peterborough, "Automatic Control Using Computers for Machine Tools," M. Monks, 7.30 p.m. ★ LONDON GRADUATE SECTION: Whole-day visit to Skefco (Luton), 12.30 p.m. ★ LUTON SECTION: Hatfield Technical College, Hatfield, "Problems of Re-entry into the Earth's Atmosphere," Dr. Hilton, 7.30 p.m. ★ SOUTHAMPTON SECTION: Polygon Hotel, Southampton, "Materials Handling," R. G. Winton, 7.15 p.m.

Wed., Dec. 2.—NOTTINGHAM SECTION: Reform Club, Victoria Street, Nottingham, "Productivity from the Barrel," H. D. Ward, 7 p.m.

Thurs., Dec. 3.—LONDON SECTION: Royal Commonwealth Society, Northumberland Avenue, Strand, W.C.2, "Maintenance of a Fleet of Vehicles," J. W. Wicks, 7 p.m. ★ READING SECTION: Huntley and Palmers, Ltd., Gasworks Lane, Reading, "Quality Control," Frank Nixon, 7.30 p.m.

INSTITUTION OF THE RUBBER INDUSTRY

Mon., Dec. 7.—N.E. SECTION: Eldon Grill, Grey Street, Newcastle, "Protection of Chemical Plant," L. Crompton, 7 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

To-day, Nov. 27.—MIDLAND COUNTIES BRANCH: James Watt Memorial Institute, Great Charles Street, Birmingham, "A Commentary on the New British Standard 449 (1959). The Use of Structural Steel in Building," J. Mason, 6.30 p.m.

Tues., Dec. 1.—LANCASHIRE AND CHESHIRE BRANCH: The University, Liverpool, "Some Aspects of Model Analysis of Structures," A. W. Hendry, 6.30 p.m. ★ N. COUNTIES BRANCH: Cleveland Scientific and Technical Institution, Middlesbrough, "The Design, Fabrication and Erection of Welded Girders for the South Durham Steel and Iron Company, Ltd.'s Works at Greatham," W. G. Gentry, 6.30 p.m. ★ N. IRELAND BRANCH: Queen's University, Belfast, "Urban Motorways," G. W. Kirkland, 6.30 p.m.

Wed., Dec. 2.—N. COUNTIES BRANCH: Neville Hall, Newcastle, "The Design, Fabrication and Erection of Welded Girders for the South Durham Steel and Iron Company, Ltd.'s Works at Greatham," W. G. Gentry, 6.30 p.m.

Thurs., Dec. 3.—MIDLAND COUNTIES BRANCH GRADUATES' AND STUDENTS' SECTION: Exchange and Engineering Centre, Birmingham, "Light Alloys in Structural Work," R. M. Davies, 6.30 p.m. ★ YORKSHIRE BRANCH: Royal Station Hotel, York, "The Economics of Framed Structures," Donovan H. Lee, 6.30 p.m.

INSTITUTION OF WATER ENGINEERS

Fri., Dec. 4.—Institution of Civil Engineers, Great George Street, London, S.W.1, Winter General Meeting, "The Formation and Planning of the Medway Water Board," A. A. Chapman; "Water Supply in Ceylon," C. Rasiah and H. C. Husband, 10 a.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Nov. 27.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, Annual General Meeting, 7 p.m.

Wed., Dec. 2.—MIDLAND SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, Presidential Address, A. Russell, 7 p.m.

Fri., Dec. 4.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, Film Evening, "Nickel Matters," "The Problem of Creep in Metals," and "Spheroidal Graphite Cast Iron," 7 p.m.

LIVERPOOL METALLURGICAL SOCIETY

Thurs., Dec. 3.—The University, 146, Brownlow Hill, Liverpool, 3, "Basic Aspects of Metal Fatigue," T. Broom, 7 p.m.

NEWCOMEN SOCIETY

Wed., Dec. 2.—Science Museum, London, S.W.7, "The Development of Engineering at the Royal Arsenal," O. F. G. Hogg, 5.30 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, Nov. 27.—Lecture Theatre, Mining Institute, Neville Hall, Newcastle upon Tyne, "Some Aspects of Guided Missiles," C. Rowley, 6.15 p.m.

REINFORCED CONCRETE ASSOCIATION

Tues., Dec. 1.—N.W. BRANCH: College of Technology, Sackville Street, Manchester, "Further Developments in the Gifford-Udall Prestressing System," E. W. H. Gifford and R. E. D. Burrow, 6.45 p.m.

Wed., Dec. 2.—11, Upper Belgrave Street, London, S.W.1, "Theory, Research and the Practical Design of Reinforced Concrete," W. E. J. Budgen, 6 p.m. ★ N.W. BRANCH: Liverpool Engineering Society, The Temple, 24, Dale Street, Liverpool, "Further Developments in the Gifford-Udall Prestressing System," E. W. H. Gifford and R. E. D. Burrow, 6.30 p.m.

ROYAL AERONAUTICAL SOCIETY

To-day, Nov. 27.—MAN-POWERED AIRCRAFT GROUP: Library, 4, Hamilton Place, London, W.1, "Man As an Aero Engine," D. R. Wilkie, 7 p.m.

Tues., Dec. 1.—4, Hamilton Place, London, W.1, "Transonic Flow over Swept Wings," E. W. E. Rogers and I. M. Hall, 7 p.m.

Wed., Dec. 2.—GRADUATES' AND STUDENTS' SECTION: 4, Hamilton Place, London, W.1, "Aerodynamics of Racing Cars," F. A. Costin, 7.30 p.m.

Thurs., Dec. 3.—GLOUCESTER AND CHELTENHAM BRANCH: St. Mary's Hall, Cheltenham, "Some Servo Mechanisms for Supersonic Aircraft," S. G. Glaze, 7.30 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Tues., Dec. 1.—12, Great George Street, Parliament Square, London, S.W.1, Symposium on Space Heating with particular reference to Dwellings, 5.45 p.m.

Sat., Dec. 5.—MINING SURVEYORS' GENERAL MEETING: Institute of Advanced Architectural Studies, Micklegate, York, "Land Drainage and the 1957 Subsidence Act," S. G. Lee, 10.30 a.m.

SOCIETY OF CHEMICAL INDUSTRY

To-day, Nov. 27.—Federation of British Industries, Tothill Street, London, S.W.1, Symposium on "Corrosion Problems of the Petroleum Industry," 9.30 a.m.

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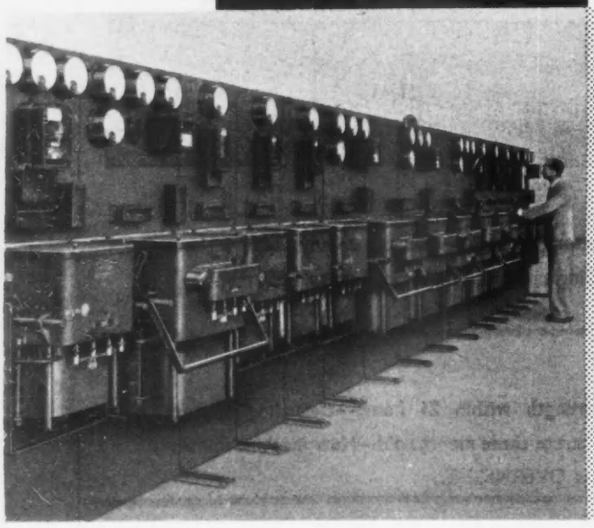
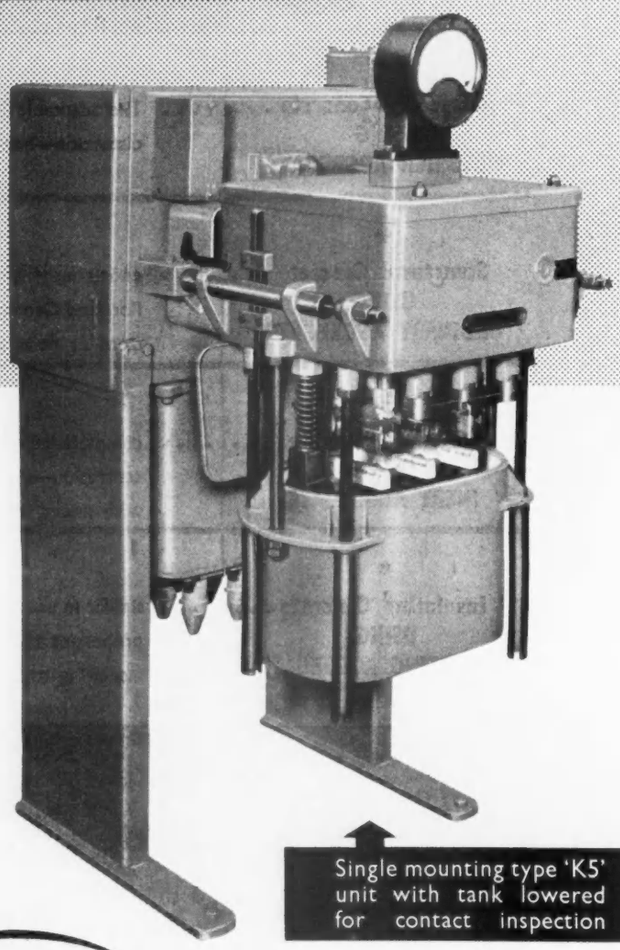


Switchboard consisting of types 'KC6' and 'KC4' units



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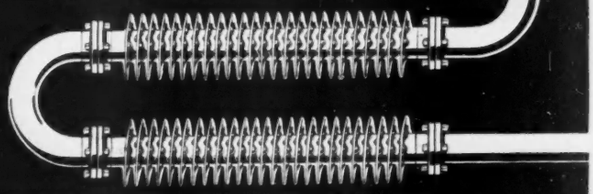

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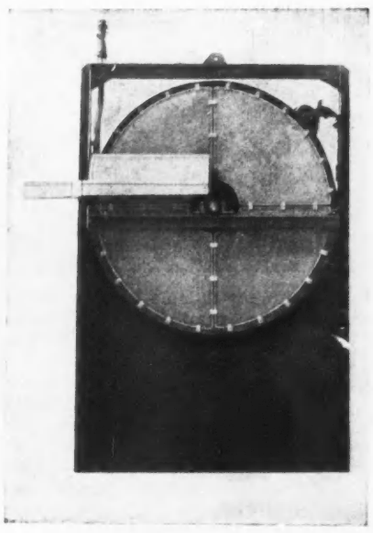

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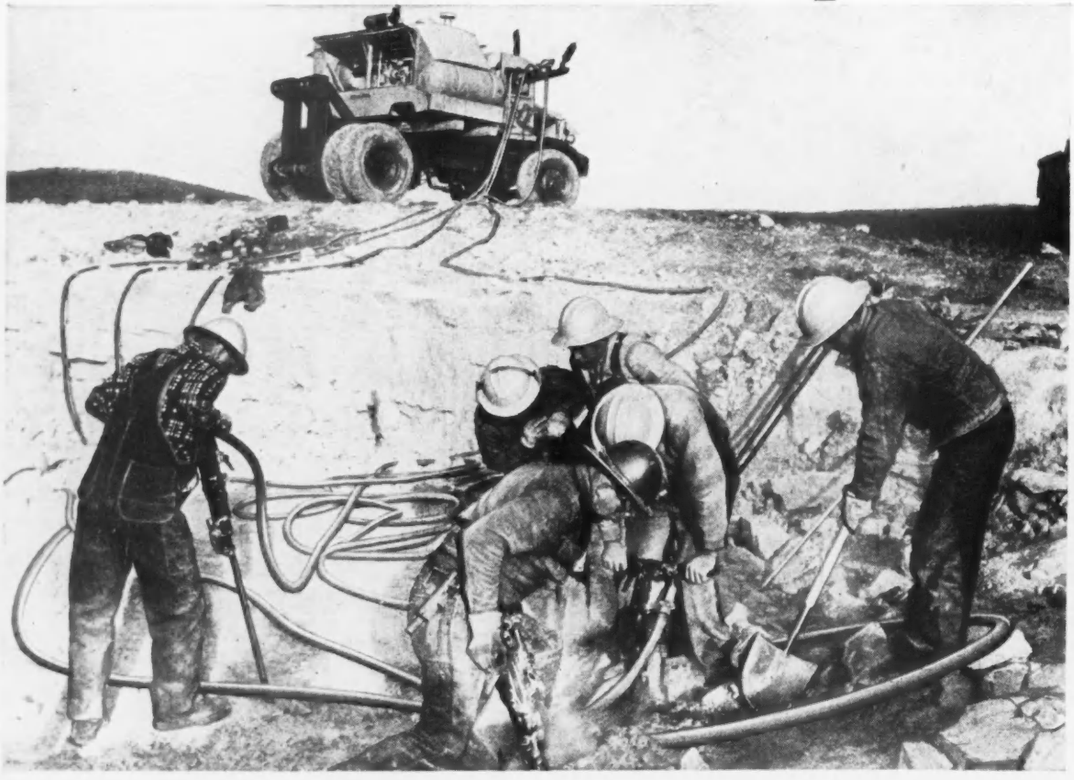

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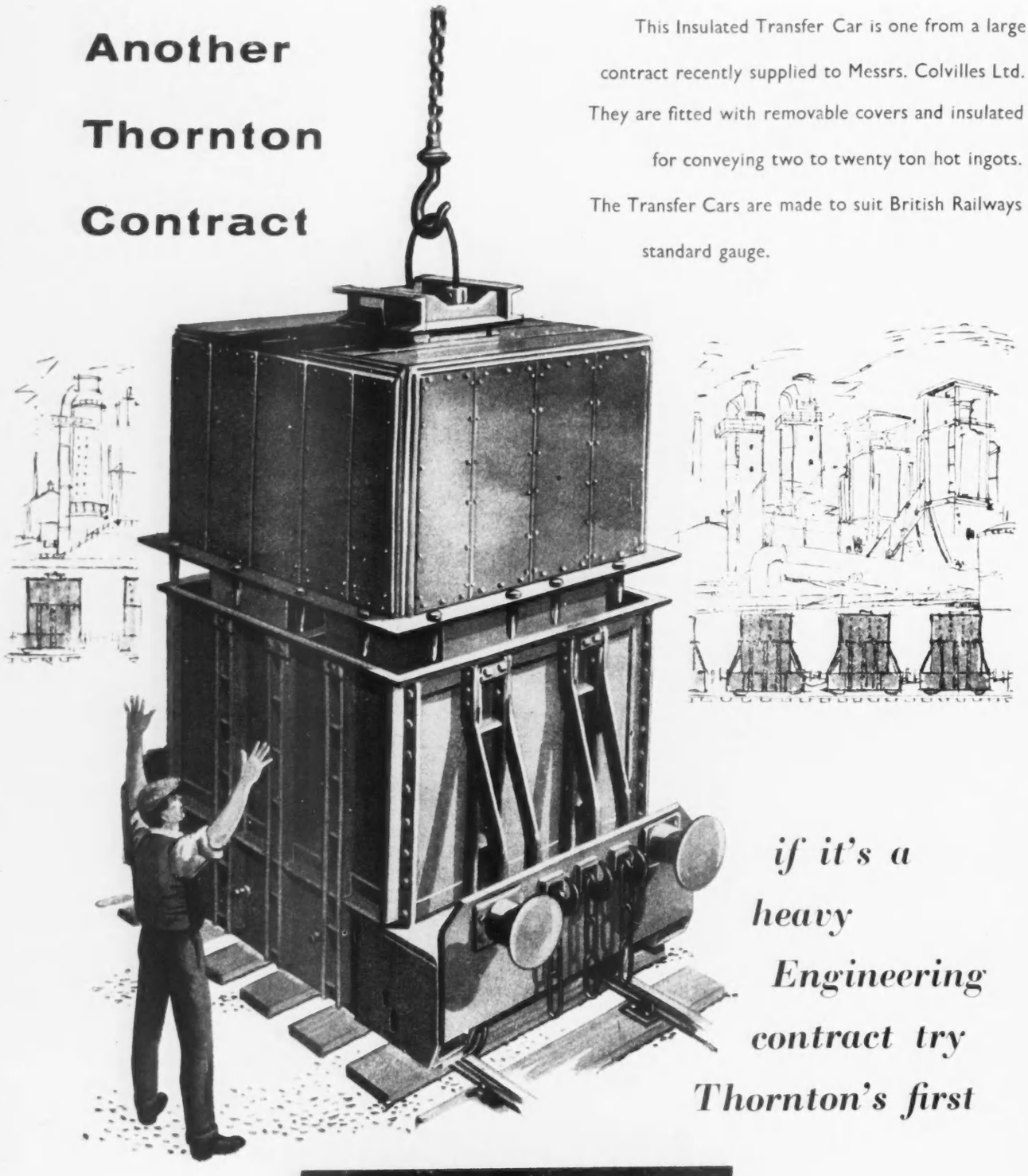

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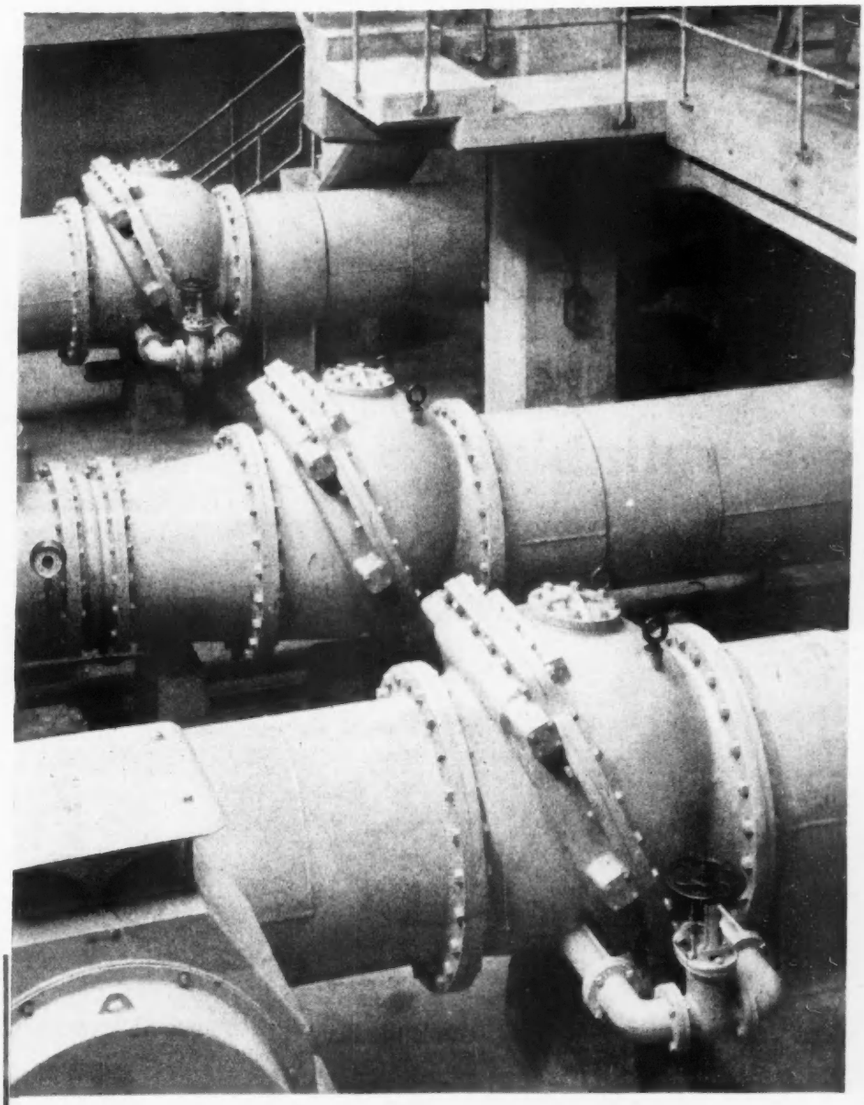

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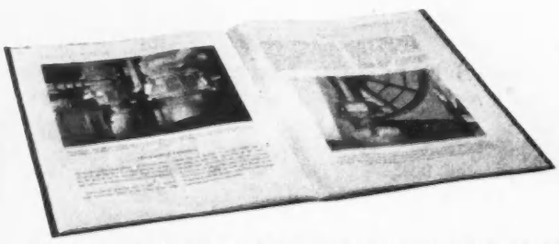

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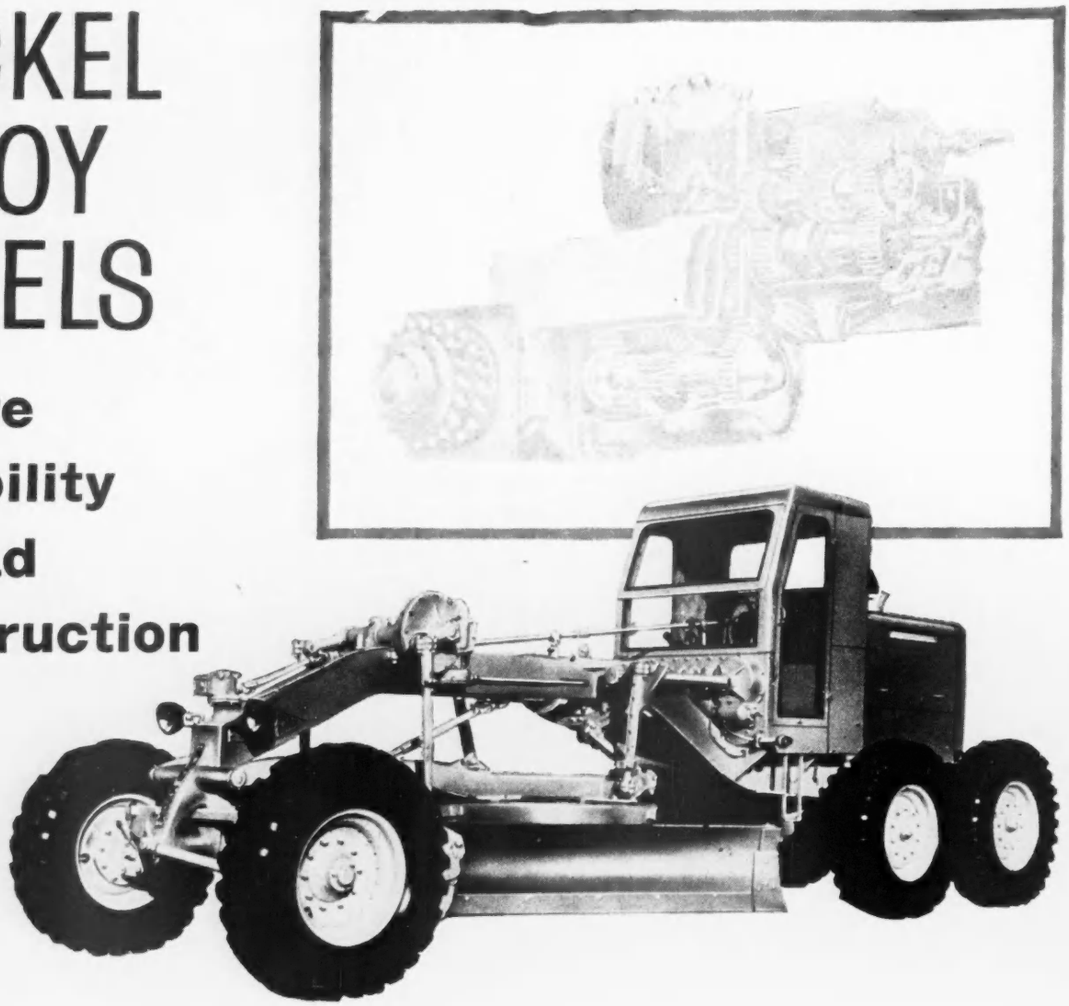

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2½" dia.	Oil quenched 830°C. tempered 650°C.	58·8	63·6	21·5	68
4" dia.	Oil quenched 830°C. tempered 650°C.	56·2	61·8	21	69
6" dia.	Oil quenched 830°C. tempered 650°C.	55·4	61·5	22	63

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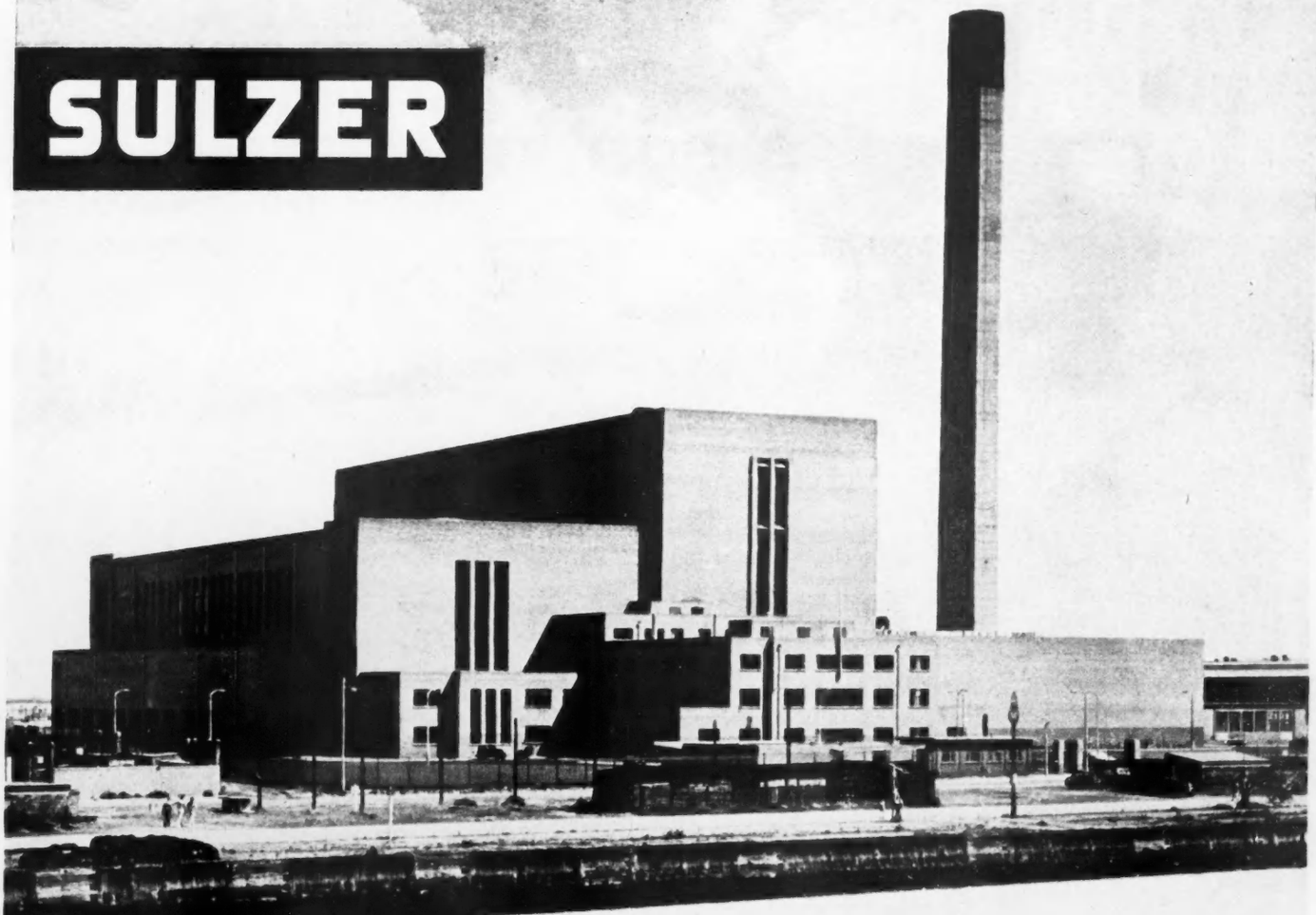

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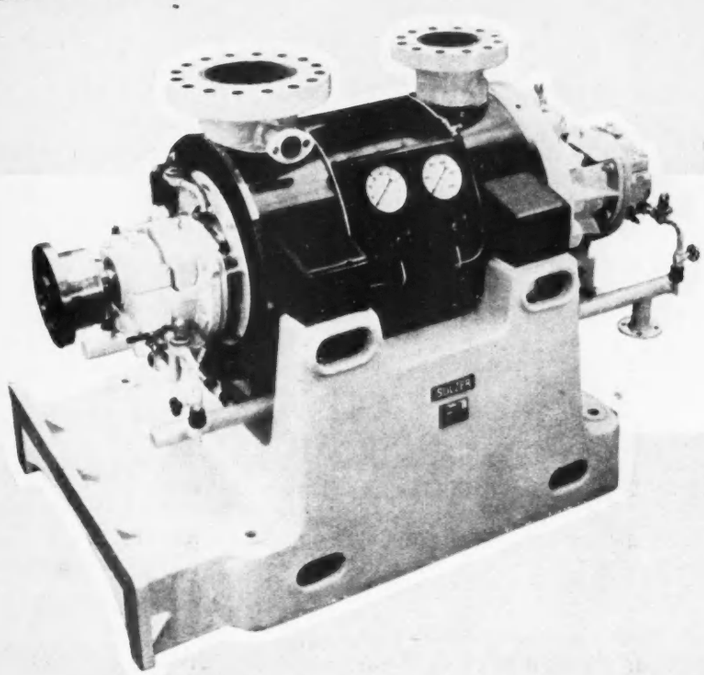

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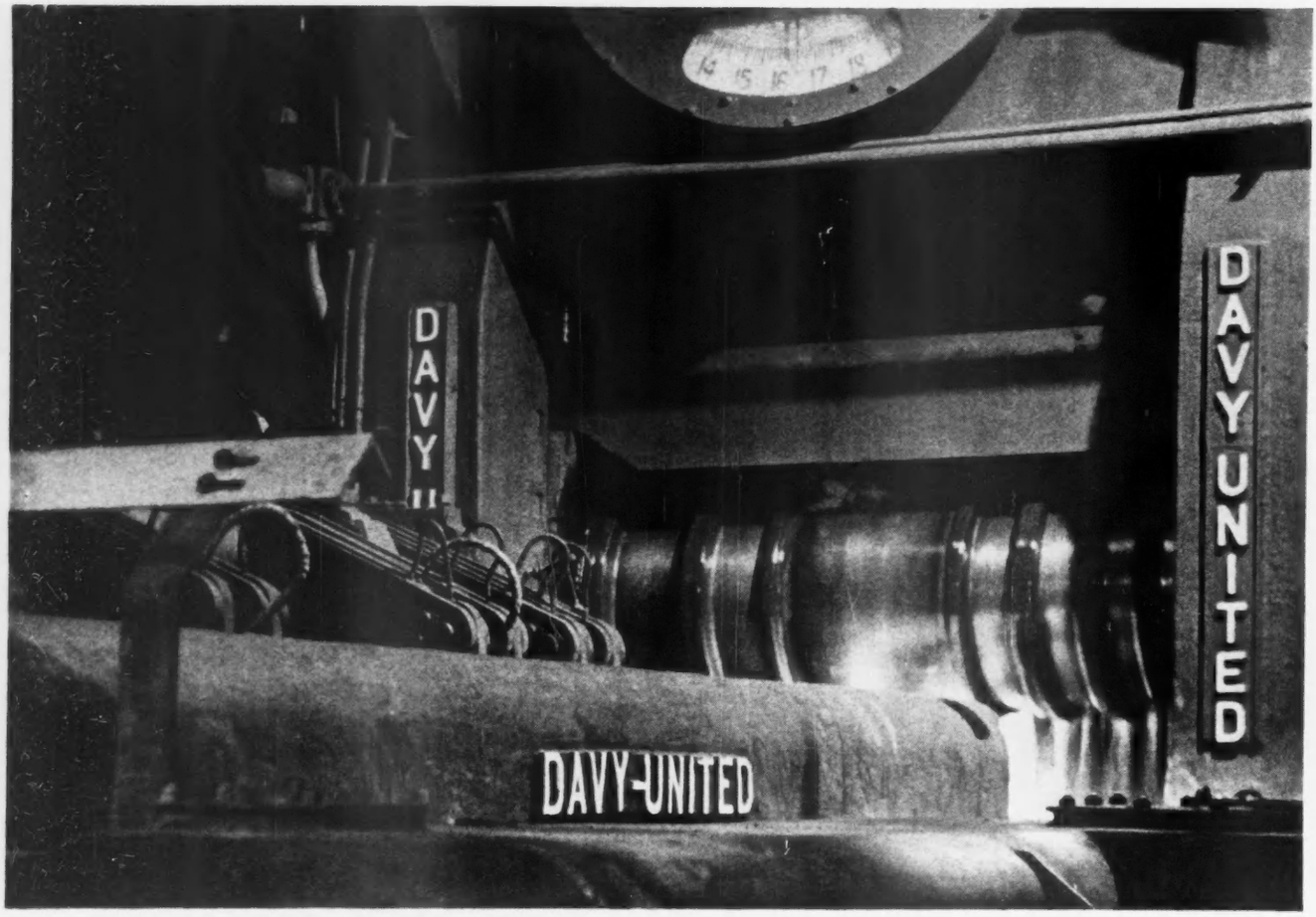

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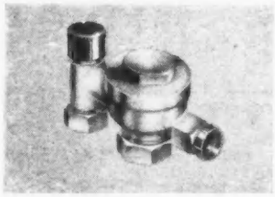

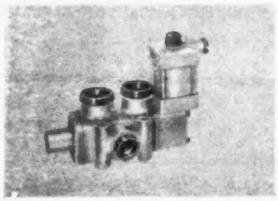

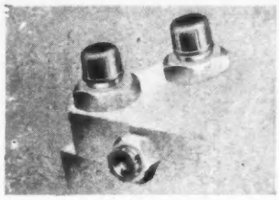

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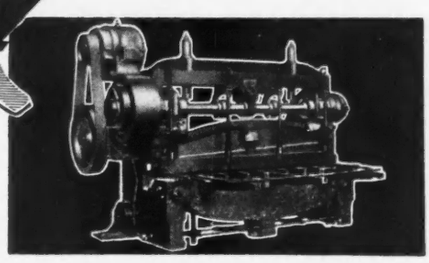

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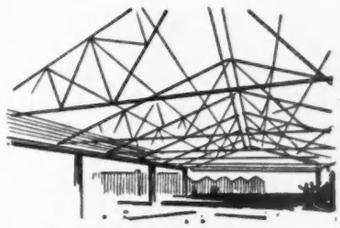

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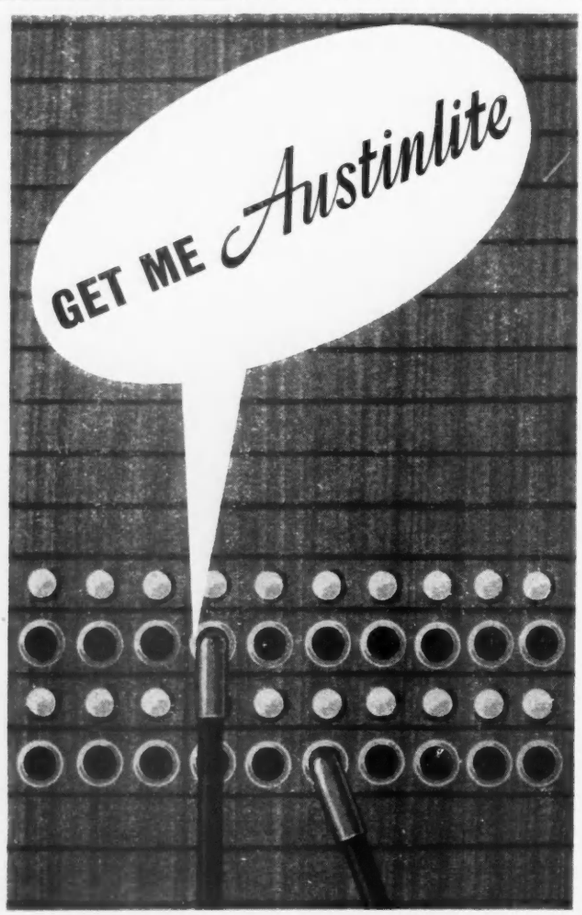

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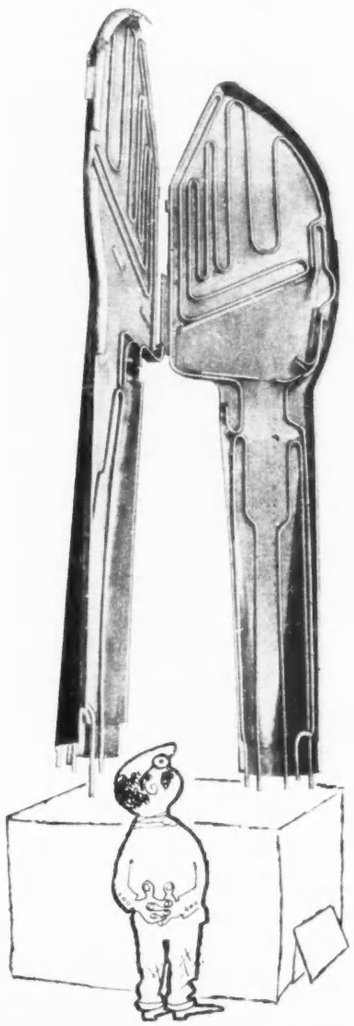

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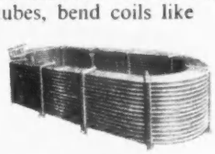

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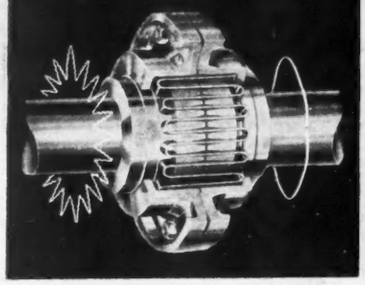

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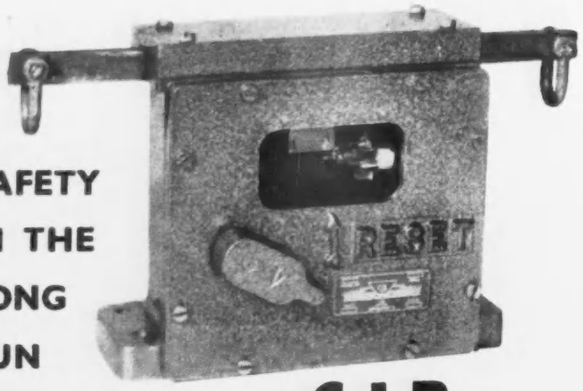

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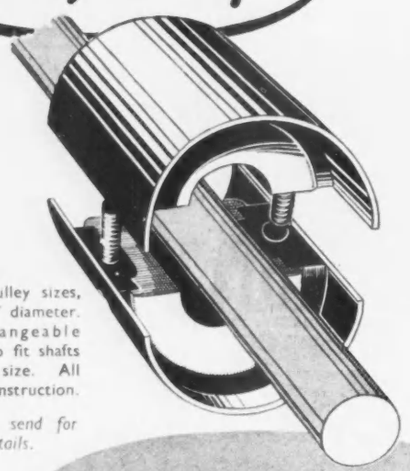

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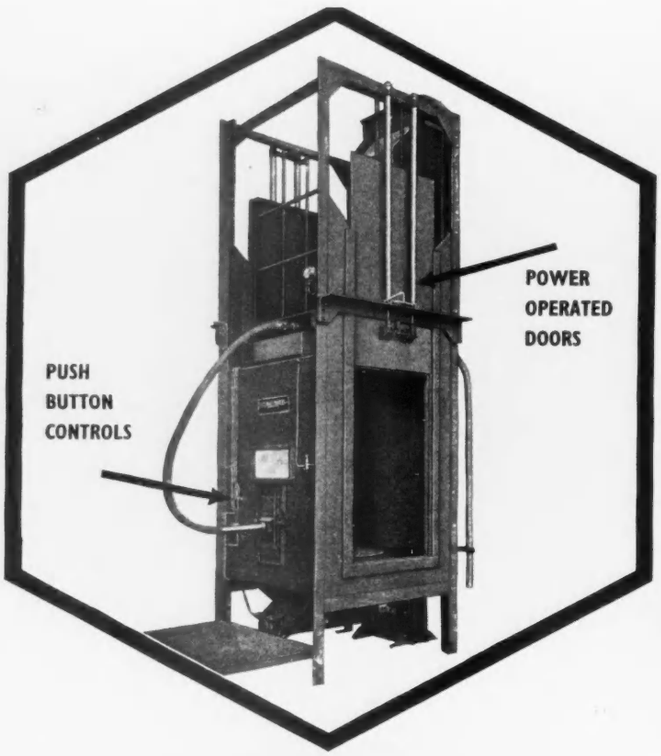

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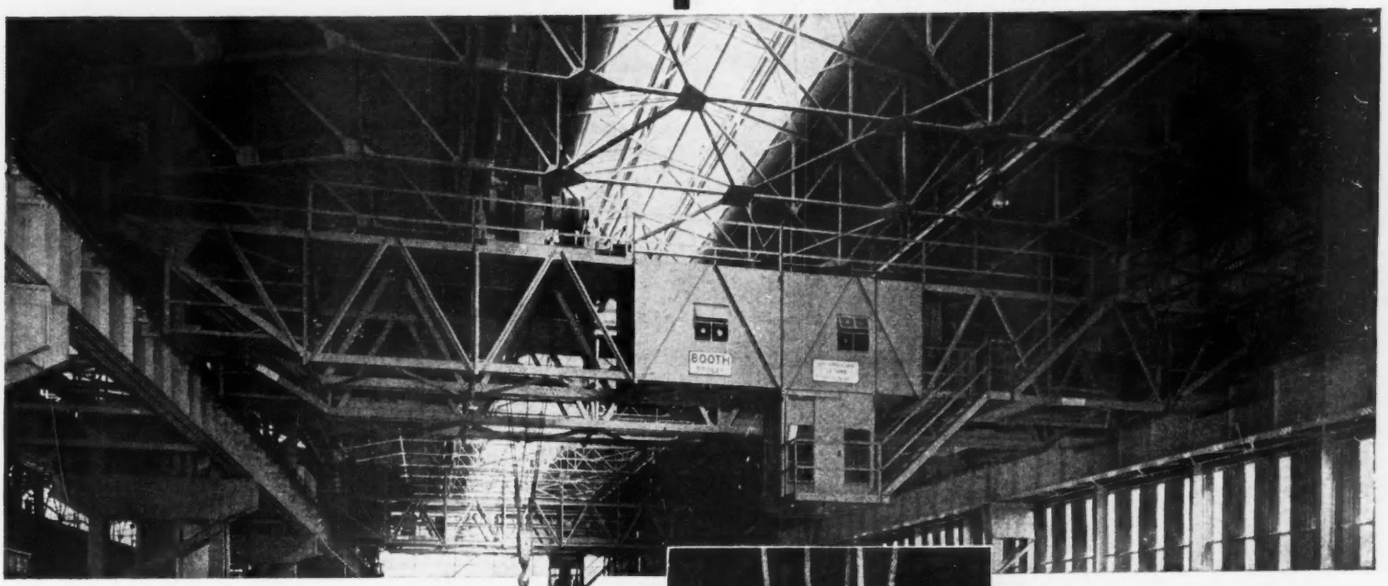
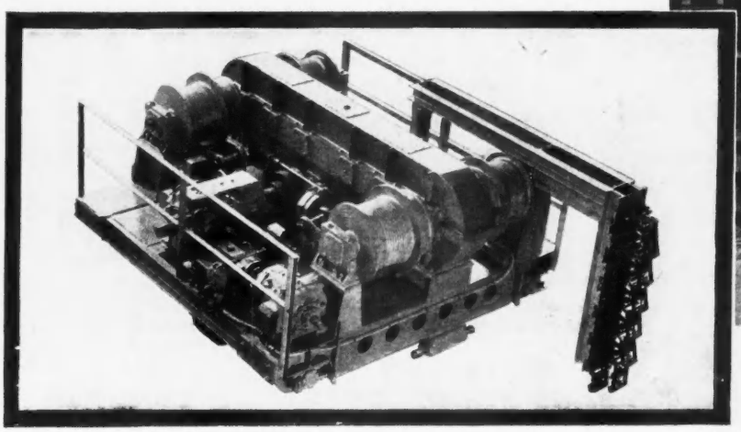


(ABOVE) Clyde-Booth four point suspension electric overhead travelling magnet crane at Messrs. Colvilles Ltd., Ravenscraig Works.
(RIGHT) The hook with slip-ring gear for the magnet, showing attachment of the four ropes.
(BELOW) The special four barrel crab.



With the introduction of higher rates of acceleraton and braking on traversing and long travel motions, in order to get the maximum output from overhead travelling cranes, magnet cranes with multiple splayed ropes are finding favour.

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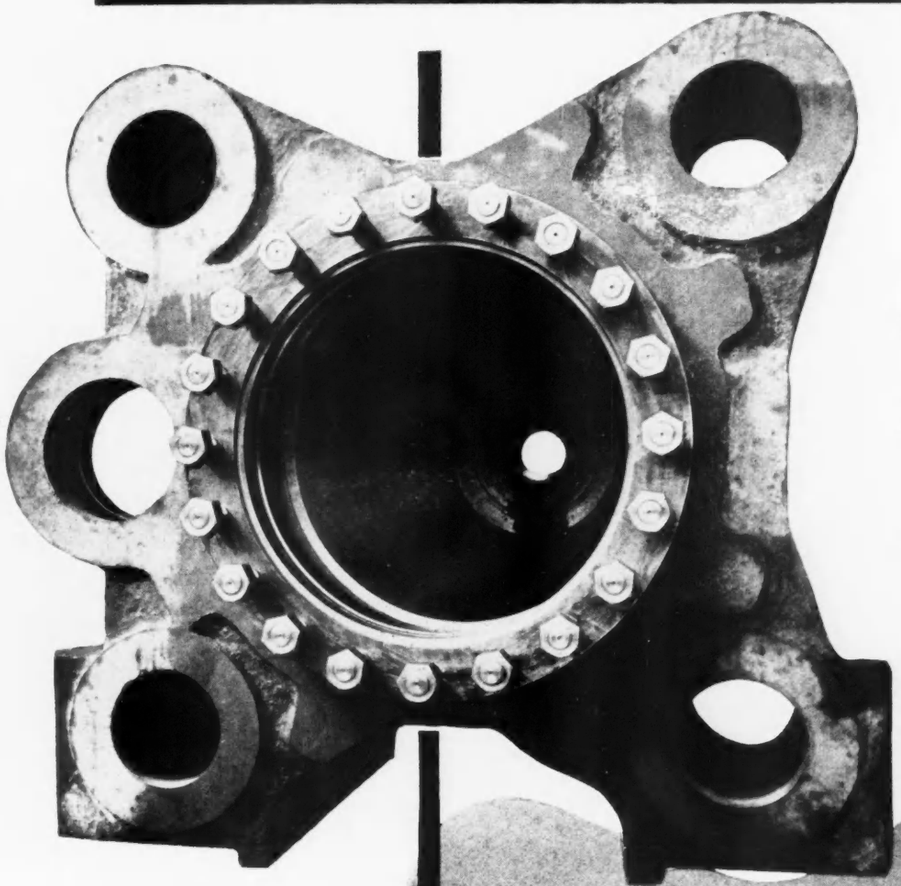

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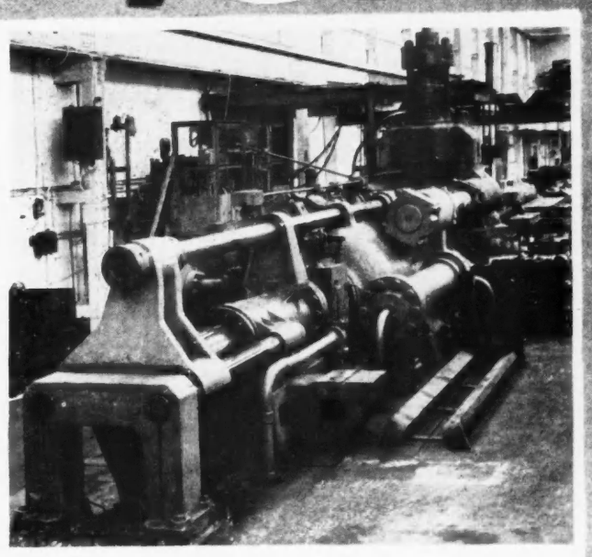

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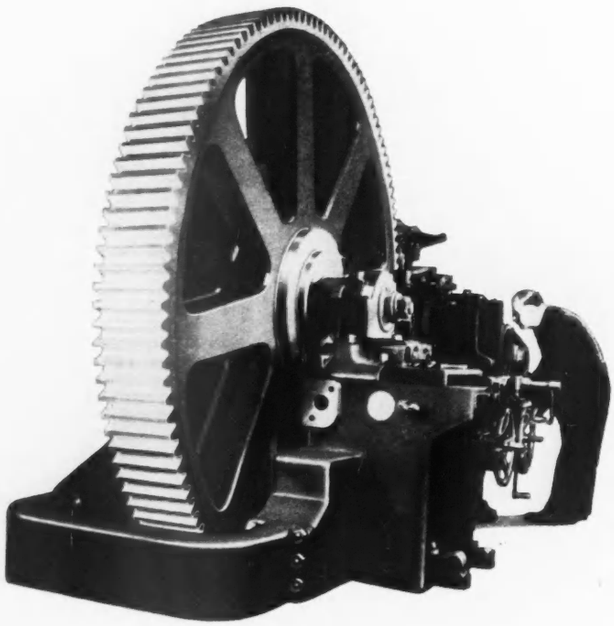

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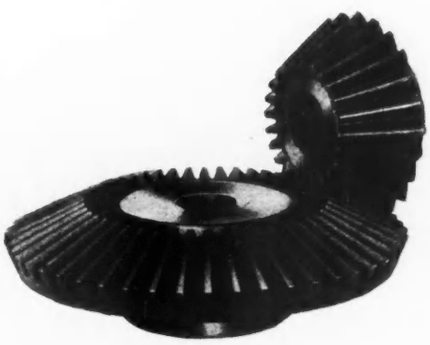

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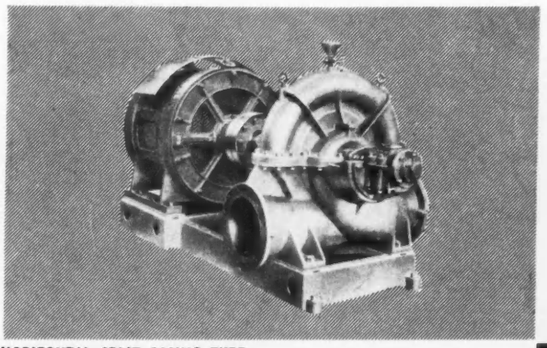
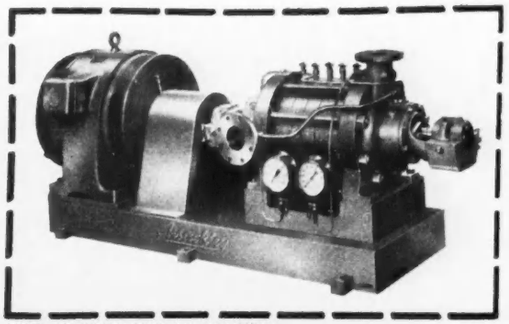


HORIZONTAL SPLIT CASING TYPE



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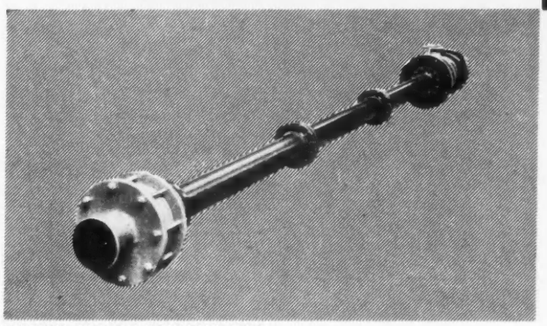

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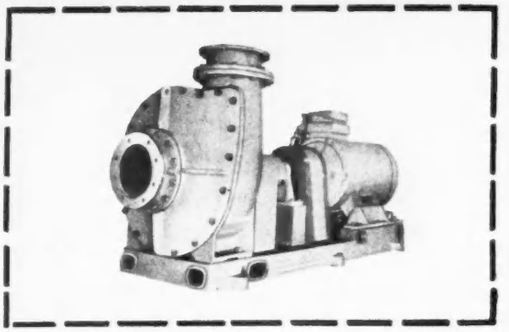

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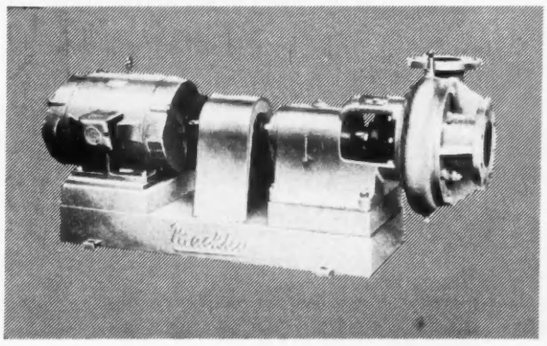

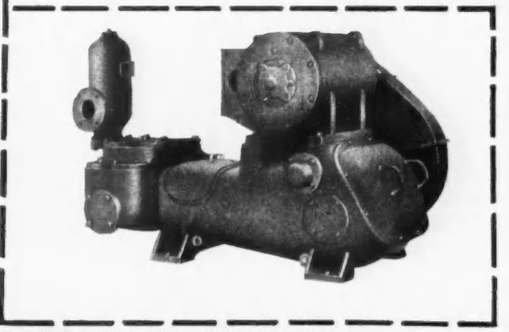

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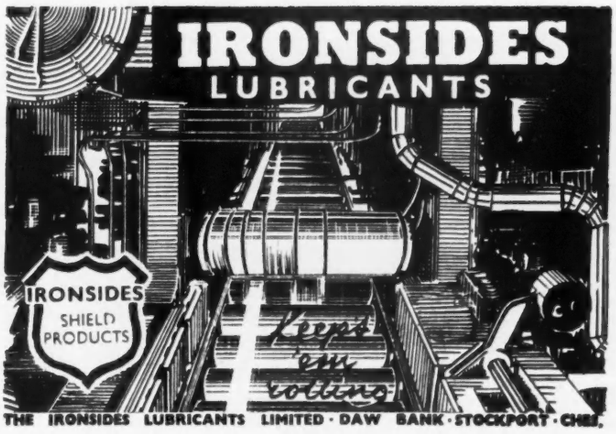

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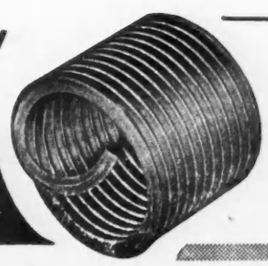

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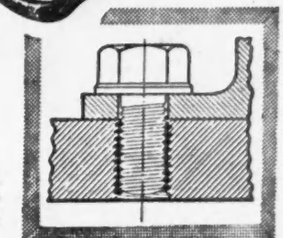

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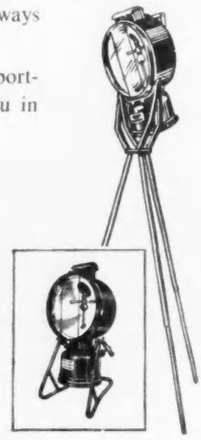

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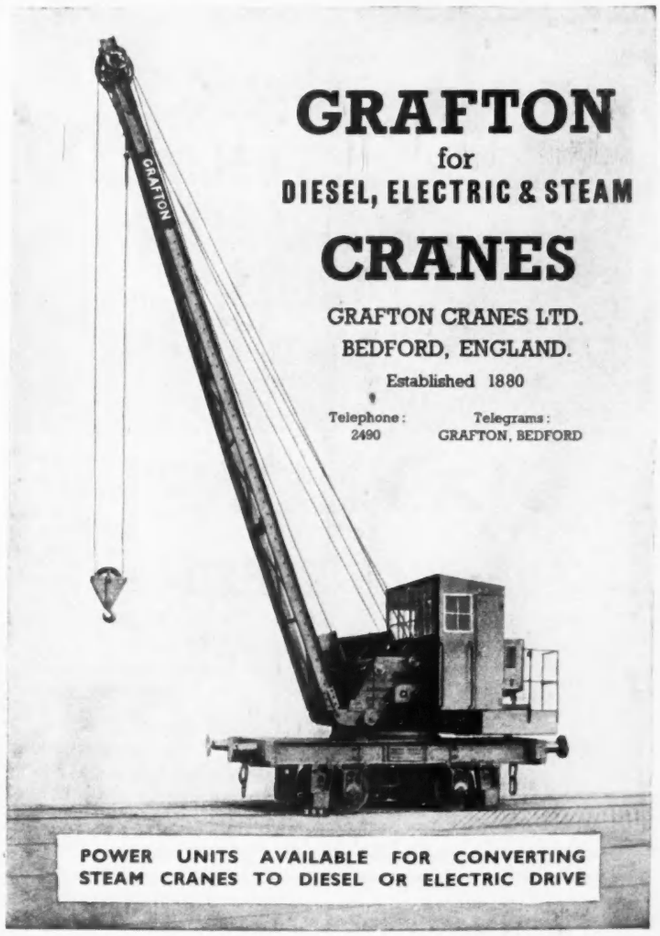

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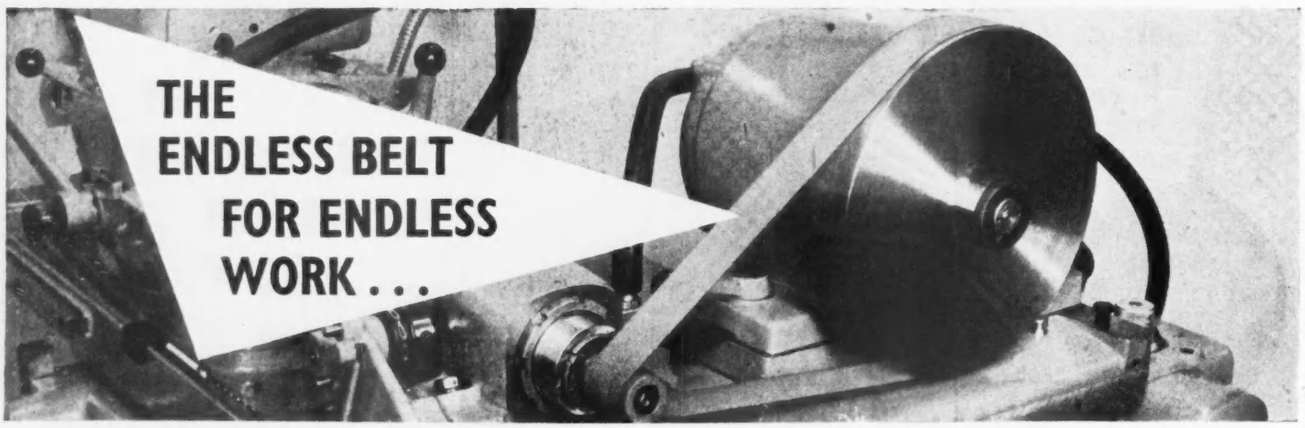

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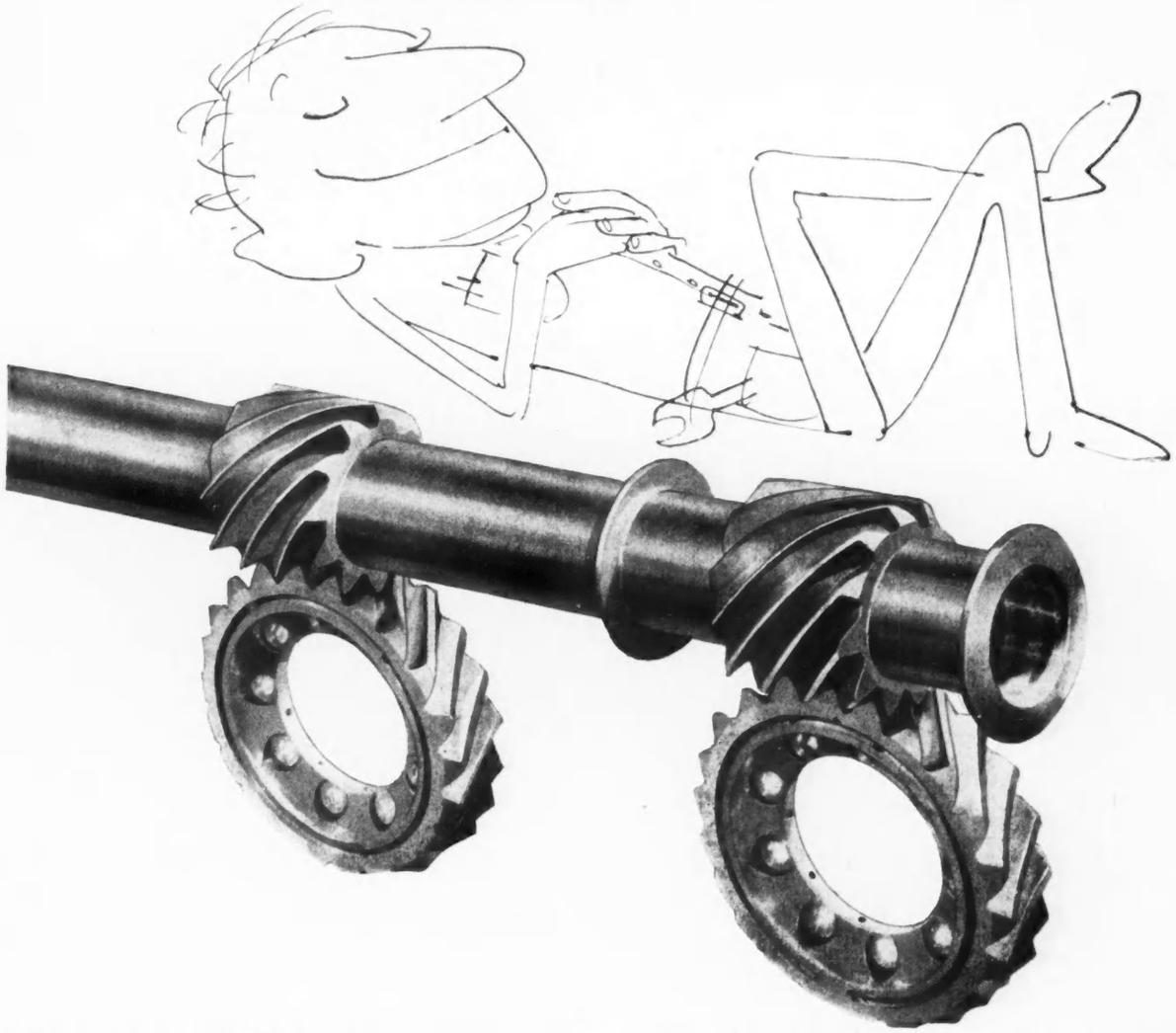

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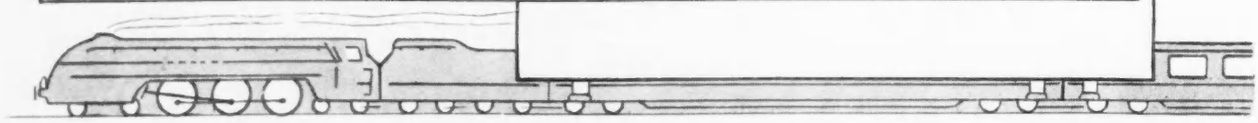

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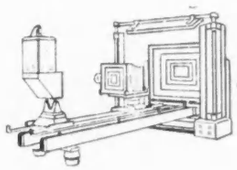

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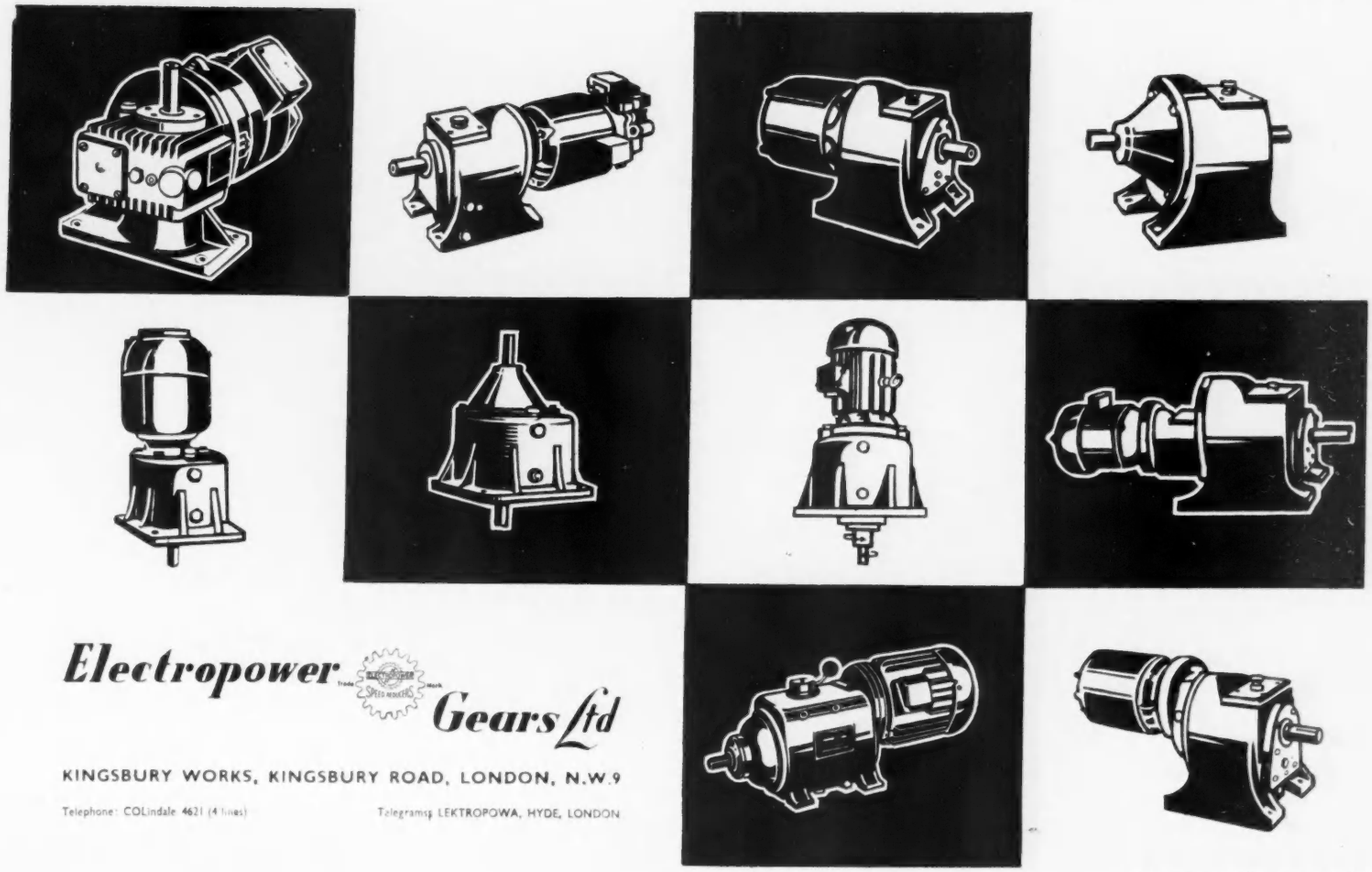

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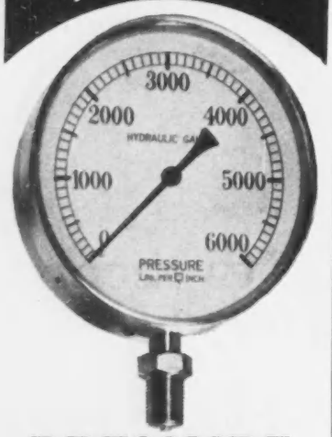

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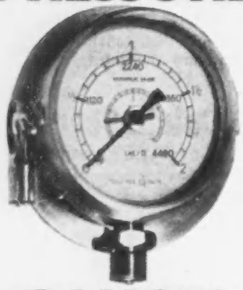

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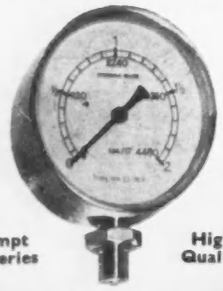

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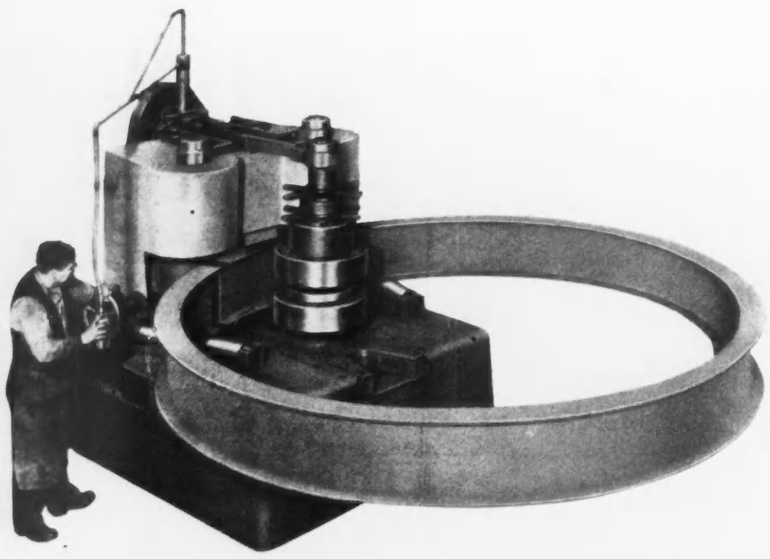

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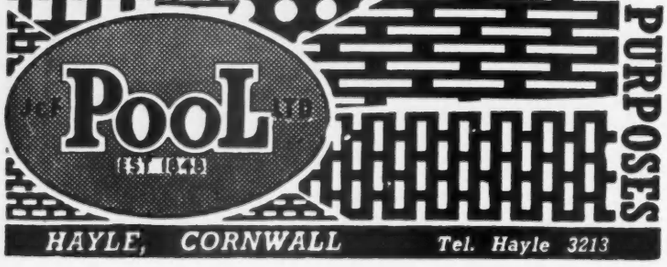

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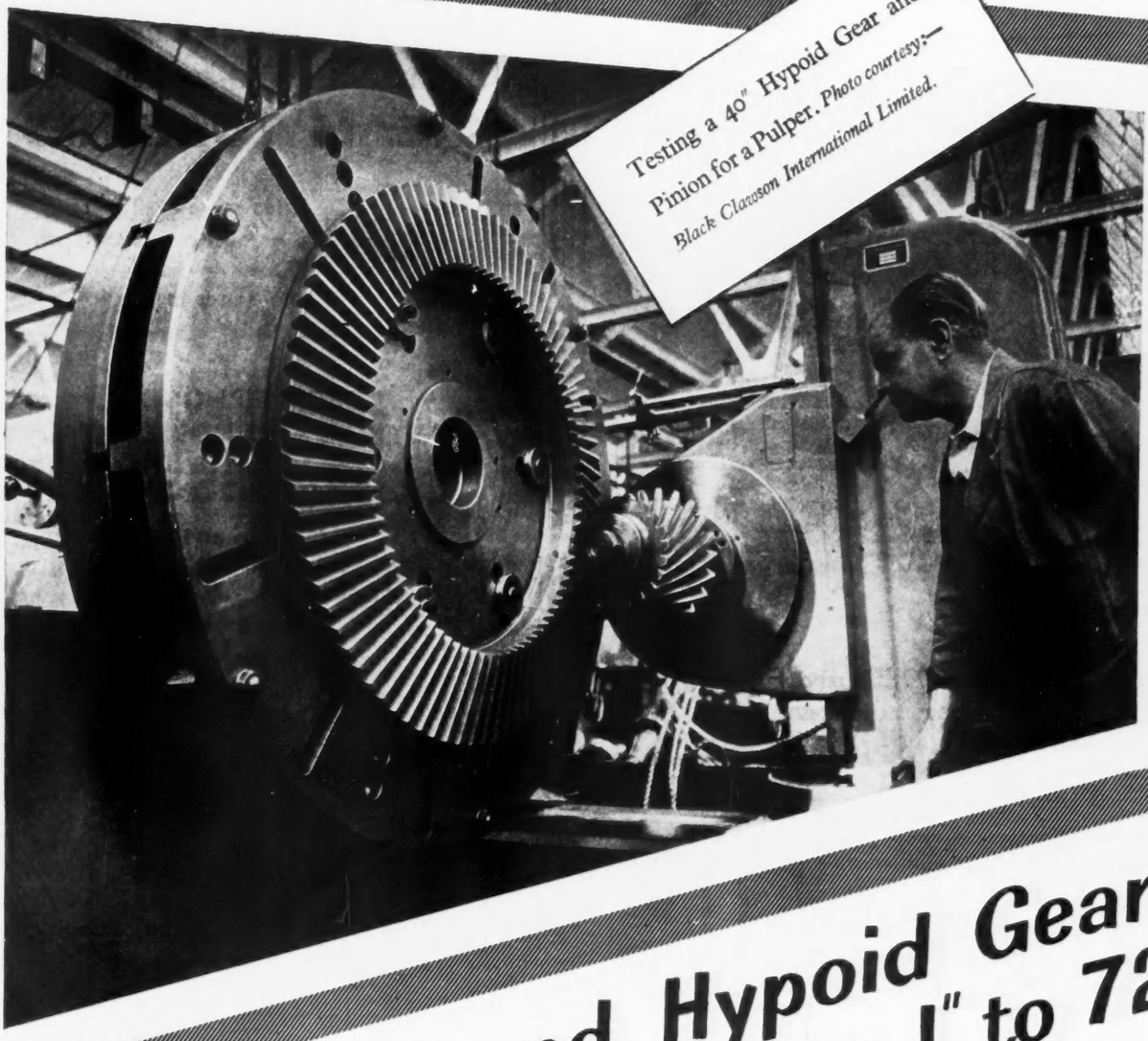

Testing a 40" Hypoid Gear and Pinion for a Pulper. *Photo courtesy:— Black Clawson International Limited.*

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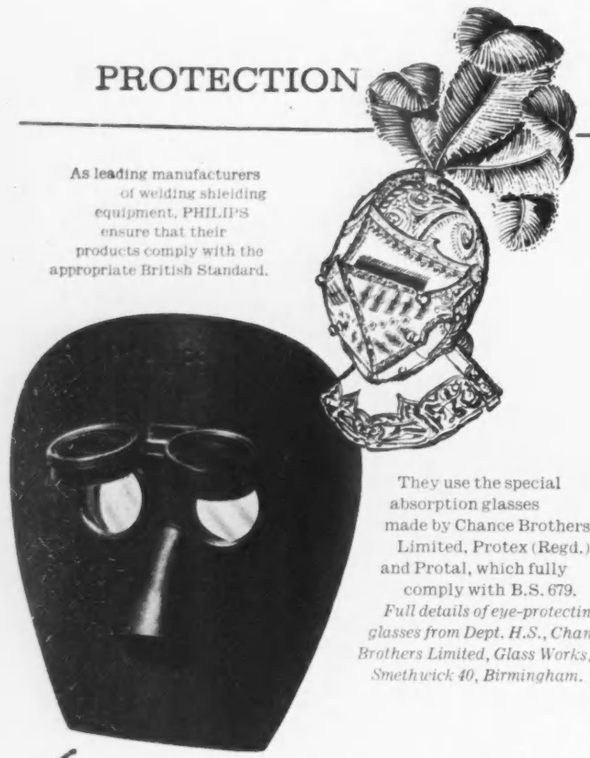

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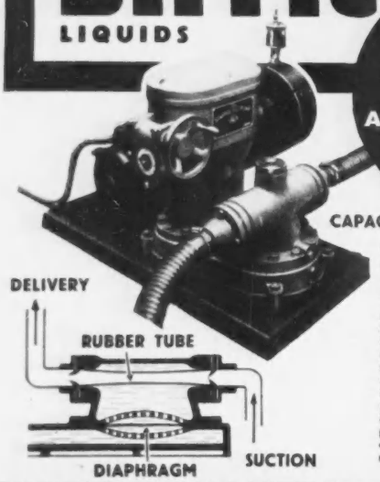

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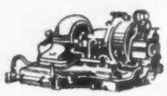

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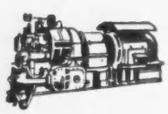

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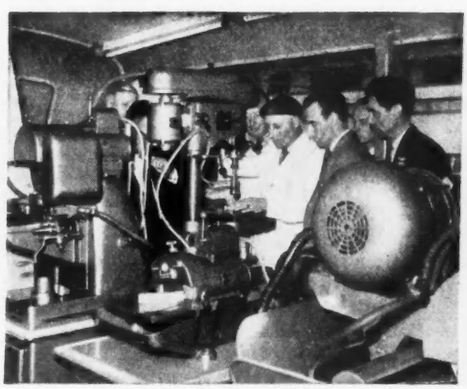

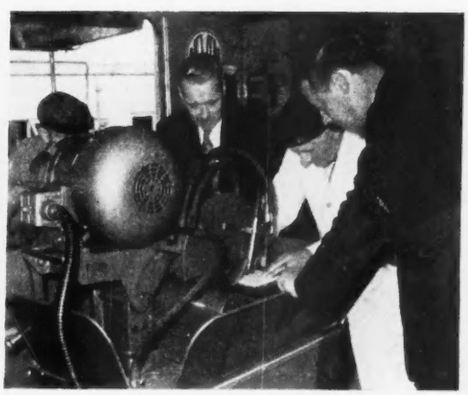

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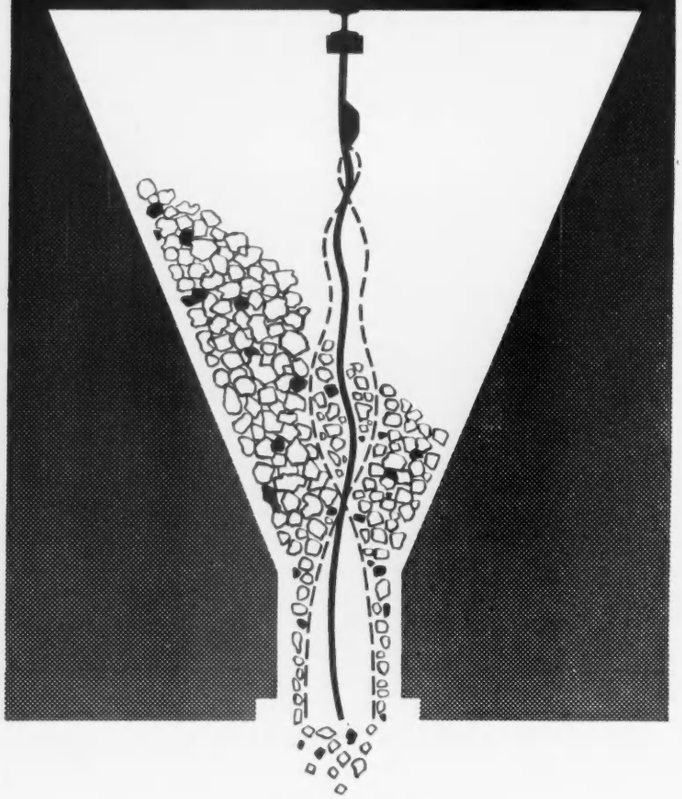

The problems of efficient discharge of material from large storage bunkers where external vibration is impractical is simply overcome by the installation of the new Sinex Internal Bunker Vibrator. The device comprises a Sinex rotary electric vibrator attached to a steel reed which hangs down into the bunker. The unit is suspended from a rolled steel joist and anti-vibration mountings protect the hopper structure itself. Maximum amplitude occurs at the tip of the reed or at the point where stoppage has built up, releases the material and ensures a smooth, free flow. Sinex Internal Bunker Vibrators are completely reliable, the power unit being readily accessible and causing no obstruction to the material inside the hopper.

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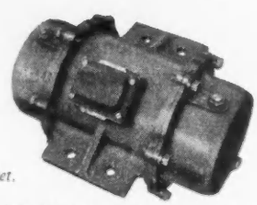
INTERNAL BUNKER VIBRATOR

A new range of Sinex rotary electric vibrators has been designed to eliminate disadvantages normally associated with this equipment. Available in four sizes providing centrifugal forces up to 300, 500, 1,960 and 7,600 lb. respectively.



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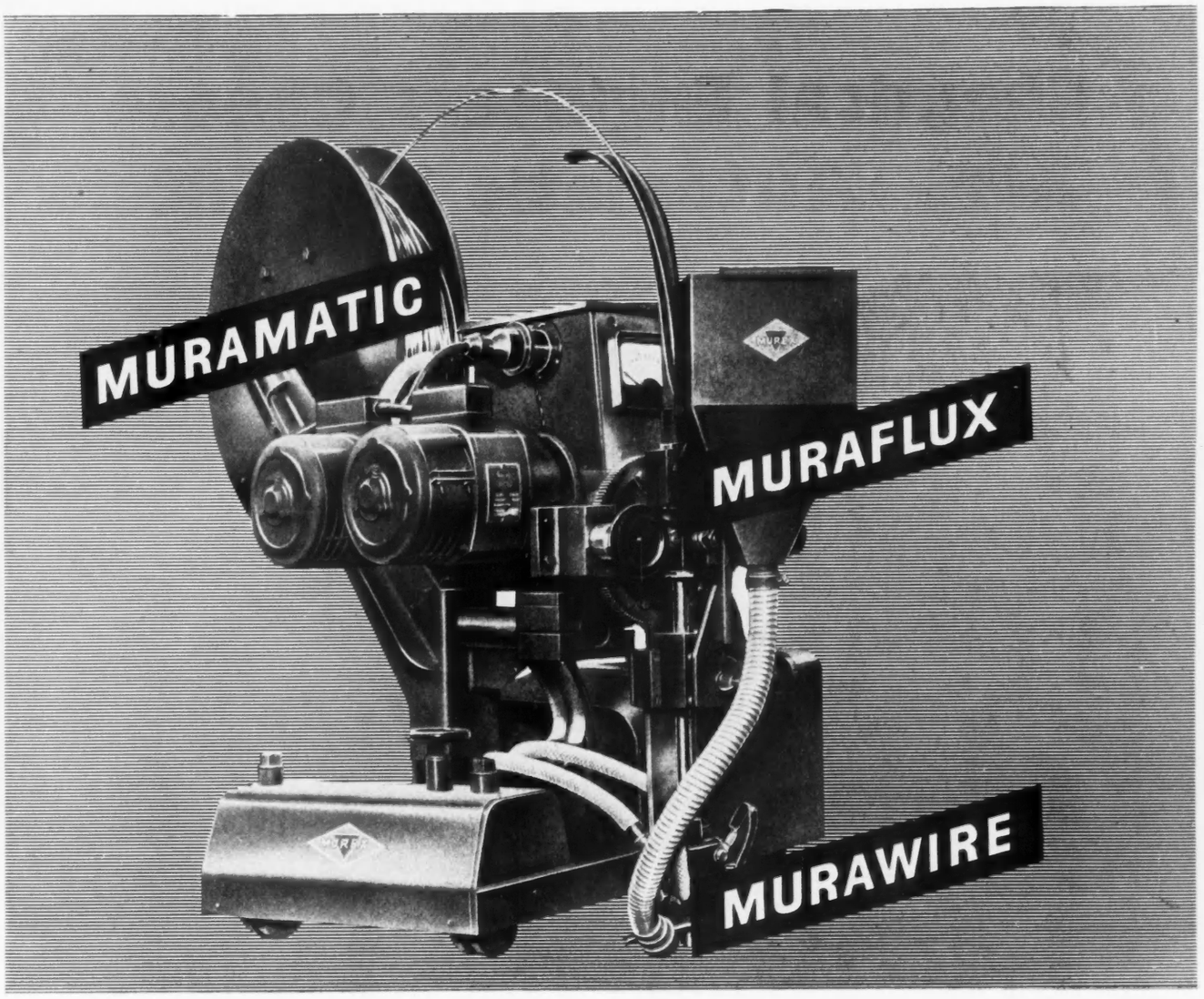

MUREX PRODUCTS for automatic welding ...

New Murex products for automatic metal arc welding are the "Muramatic" automatic equipment, "Muraflux" granular fluxes and "Murawire" filler wire. With the Murex "Coilex" electrode, these new products make available a complete Murex service for automatic arc welding.

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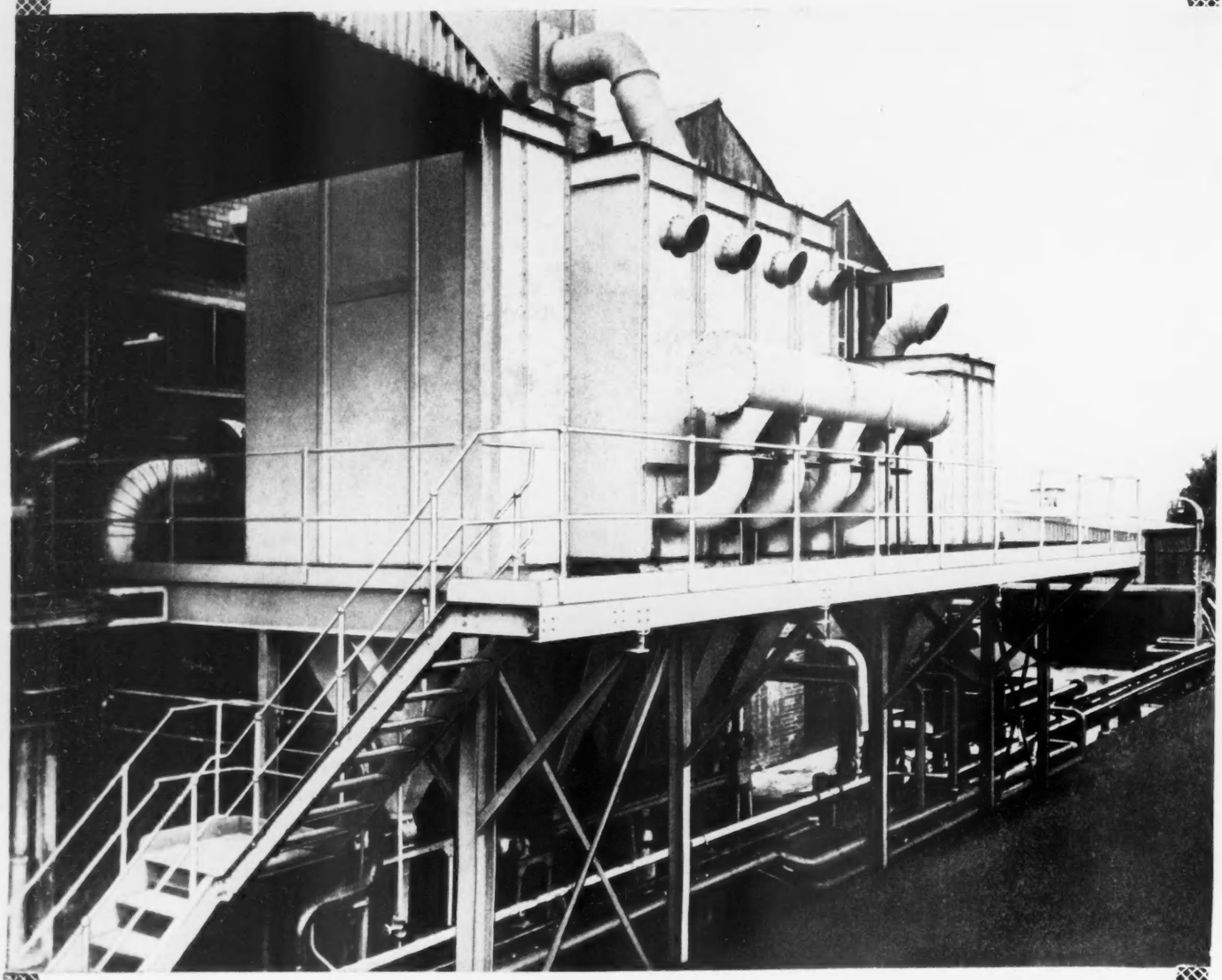

On the plant recently installed by Simon Handling Engineers, Ltd., for Imperial Chemical Industries, Ltd., Clitheroe, Tilghman automatic bag filters were chosen to remove and contain the very fine oxide powders from various mixing, pelletising and process handling points, etc.

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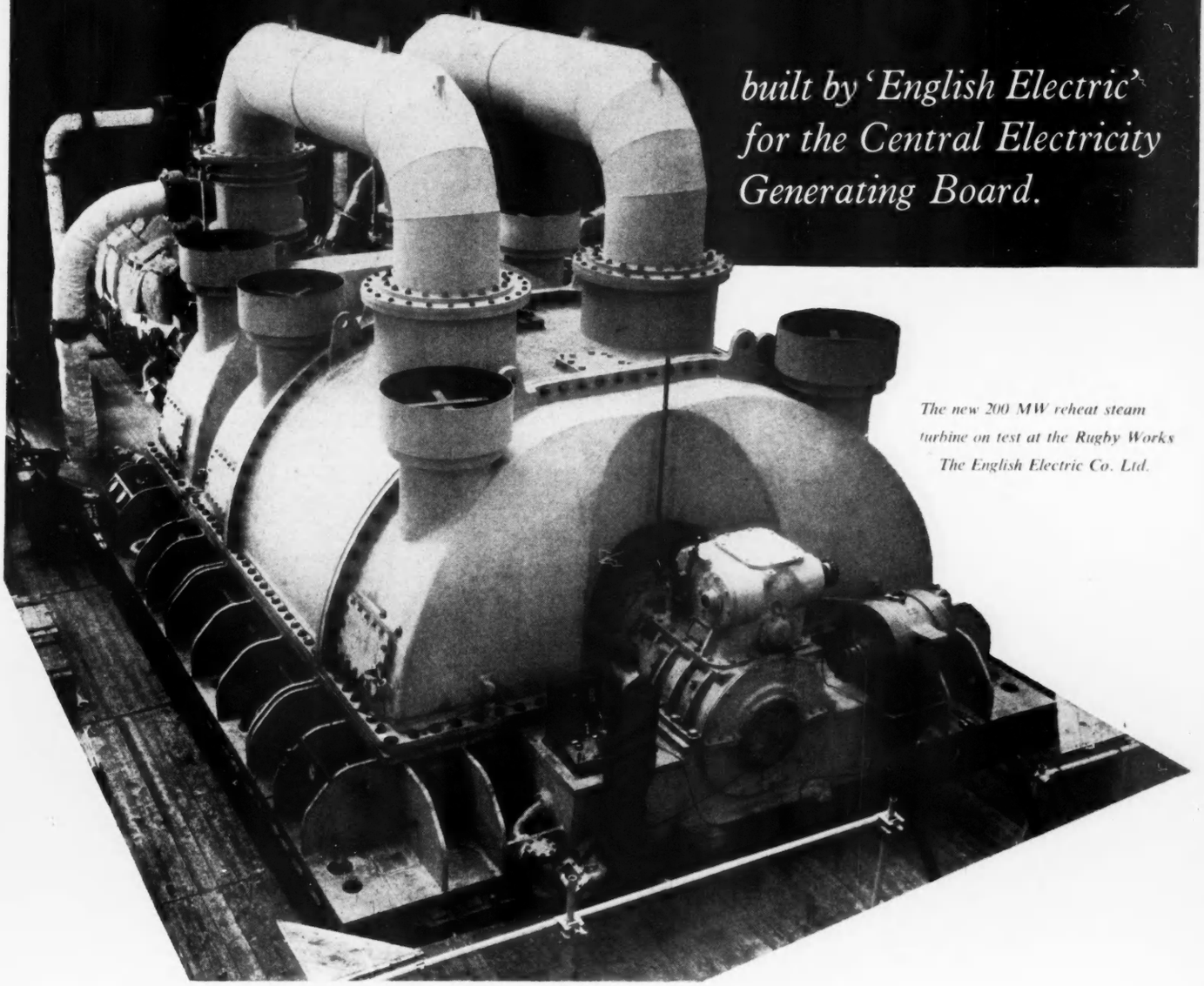
built by 'English Electric' for the Central Electricity Generating Board.



The new 200 MW reheat steam turbine on test at the Rugby Works The English Electric Co. Ltd.

The first of the five 200 MW turbo-alternator units ordered from The 'ENGLISH ELECTRIC' Company for the Board's 1,000 MW power station at High Marnham is now installed.

It will be the first turbine in the first power station of this size in the United Kingdom to operate with the advanced steam conditions of 2,350 p.s.i.g. and 1,050° F. with reheat to 1,000° F.

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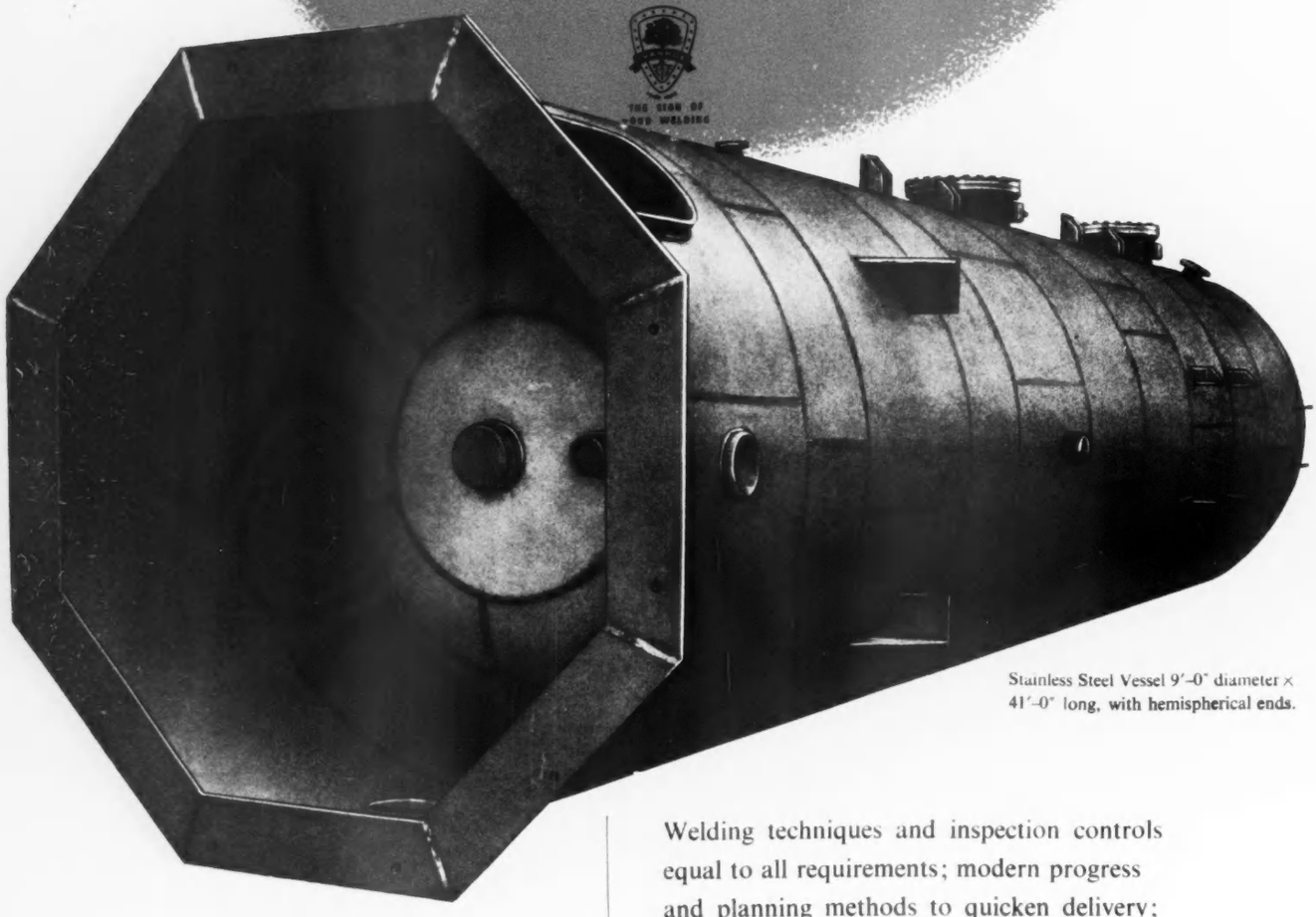
in STAINLESS STEEL, MONEL, TITANIUM, HEAVY ALUMINIUM AND MILD STEEL



Stainless Steel Vessel 9′–0″ diameter × 41′–0″ long, with hemispherical ends.

Welded fabrications and fusion-welded pressure vessels to the requirements of Lloyds Class 1, A.S.M.E., A.O.T.C. codes and similar specifications.

Welding techniques and inspection controls equal to all requirements; modern progress and planning methods to quicken delivery; capacity and full research facilities for variety of work; all these essentials are co-ordinated by Jenkins of Rotherham to provide a production potential second to none for the fabrication of welded pressure vessels.

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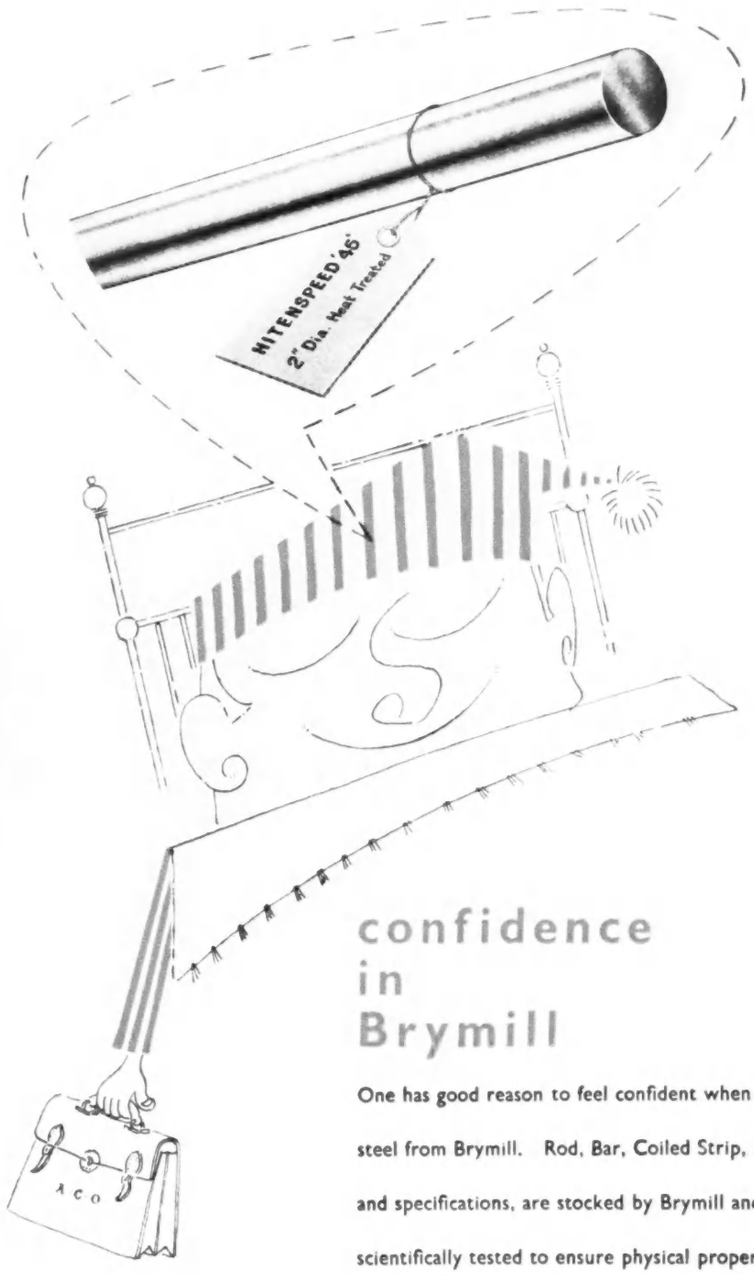

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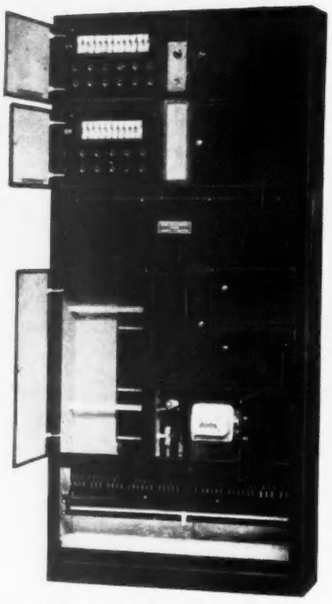
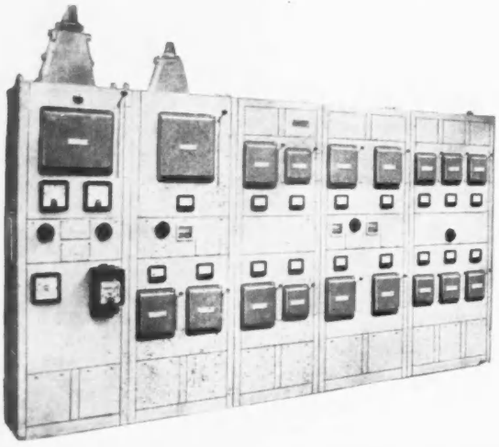
CUBICLE TYPE SWITCHBOARDS

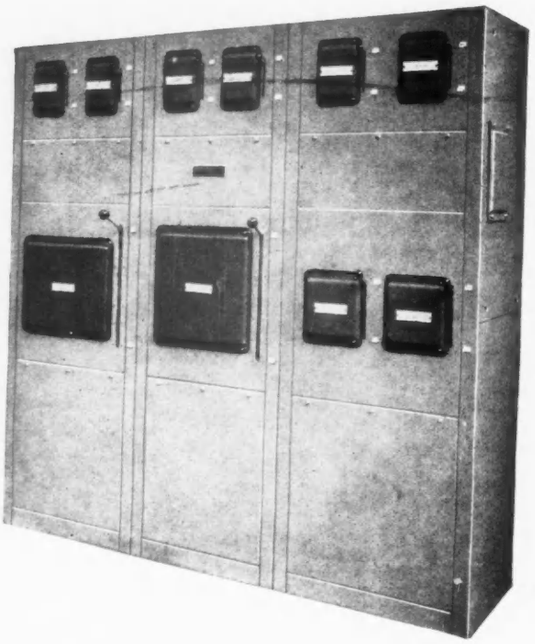


The name FLUVENT has been associated with advanced Switchboard design since the beginning of the century and the name AEROFLEX has been synonymous with high breaking capacity Fuses since they were first introduced in the early 1920's.

An unusual Cubicle Board (right) which provides a variety of lighting fuseboards with tumbler switch panels. It is installed in St. George's Chapel, Windsor.



Installed in a modern manufacturing undertaking, this Board (above) protects one 300 amp. eight 100 amp. and eight 60 amp. 3 phase 4 wire outgoing circuits, and the incoming Cubicle on the left is provided with a 600 amp. main switch and metering facilities.



A compact Board (right) protecting one 300 amp. and two 60 amp. 3 phase 4 wire circuits and six 30 amp. single phase and neutral circuits, all under the control of a 600 amp. T.P. and Neutral incoming main switch.

Publication SB3 illustrates and describes a selection of Cubicle and Unit Type Switchboards. A copy will be forwarded on request.

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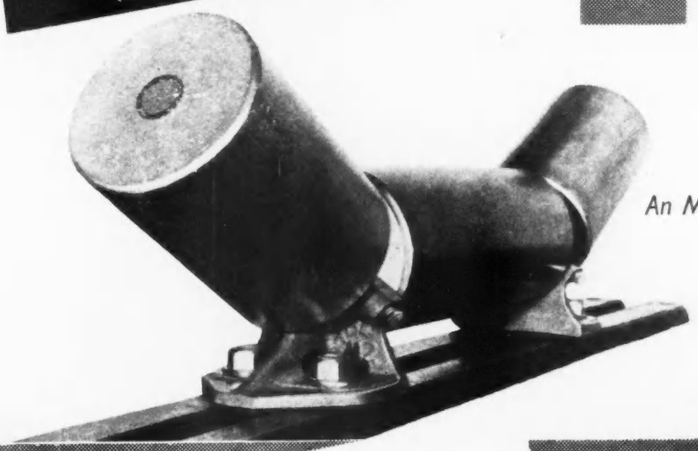

An M&C idler for a 24-in. conveyor belt.

To say that idlers are "sealed for life" is an empty phrase, for how long is "life?" A butterfly's life or an elephant's? M&C idlers are sealed for long life. Put to work as delivered and left to themselves, they will be in the best of health long after others have given up. And M&C seals can be rejuvenated at intervals, new grease driving out the old, making the seals perpetual and multiplying the life of the idlers many-fold.

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1950, the belt conveyor idlers sealed for their first life.
By arrangement, the grease gun was not used.
1959, still going strong.

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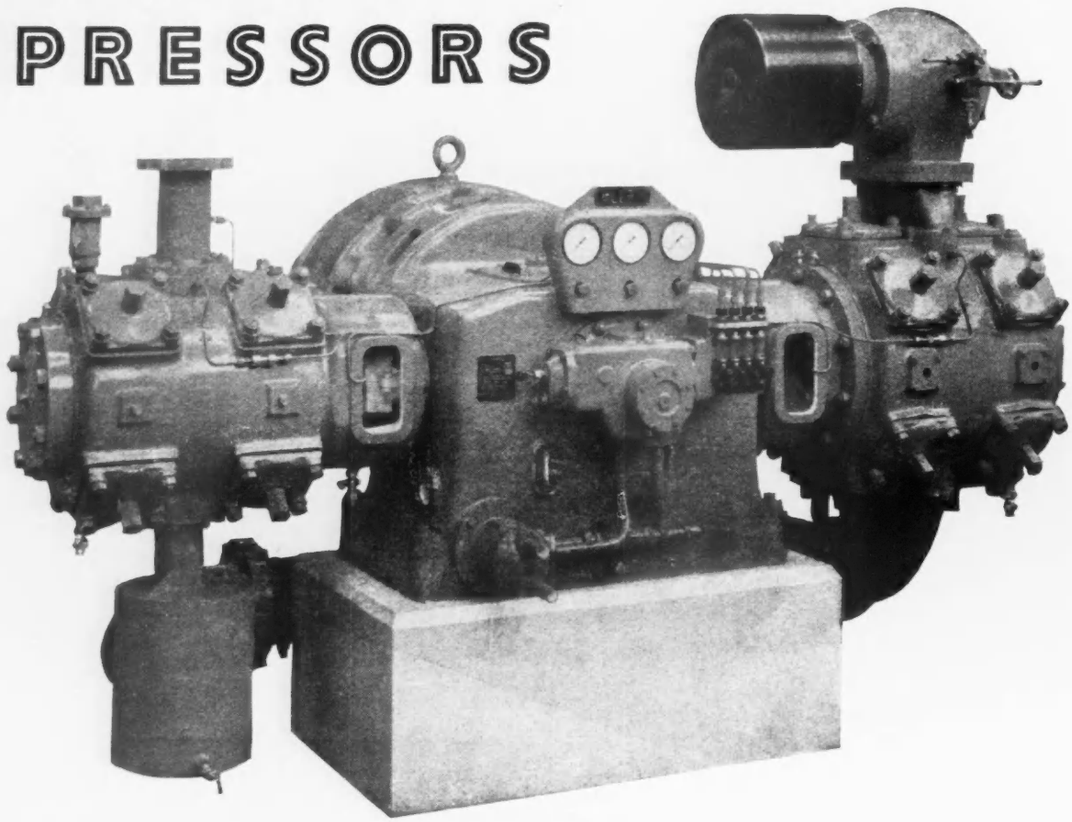

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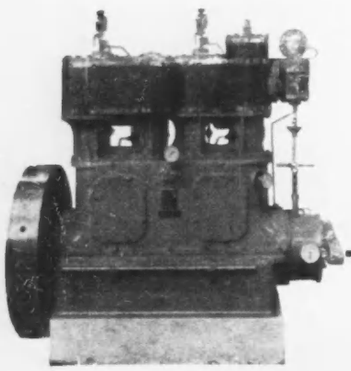

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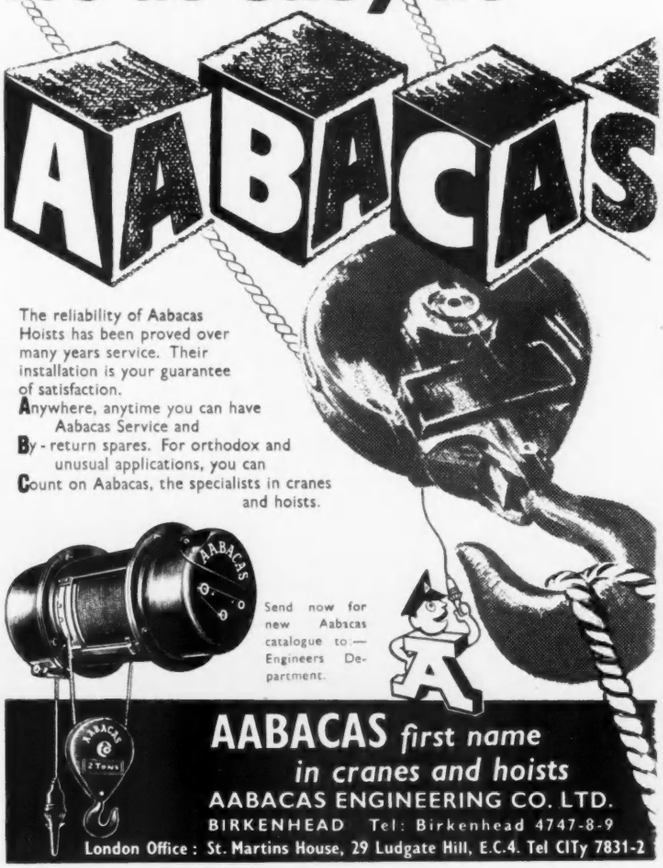

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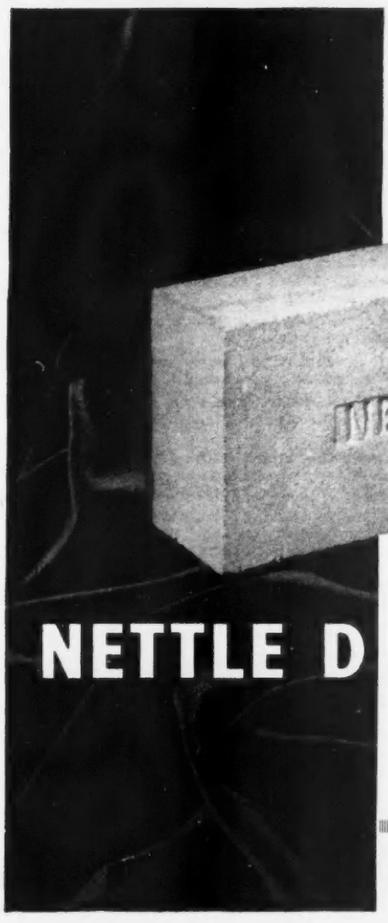

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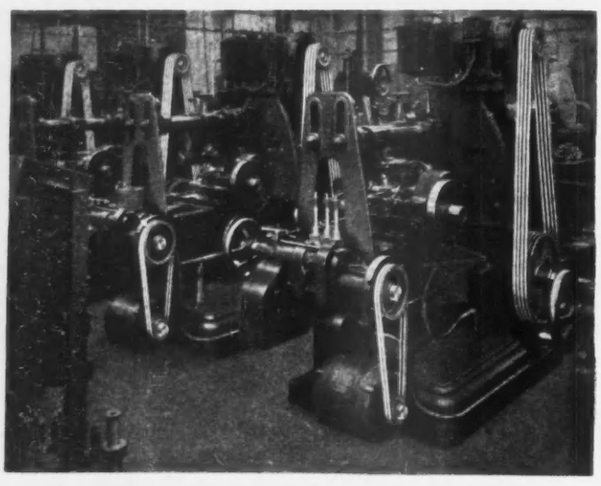

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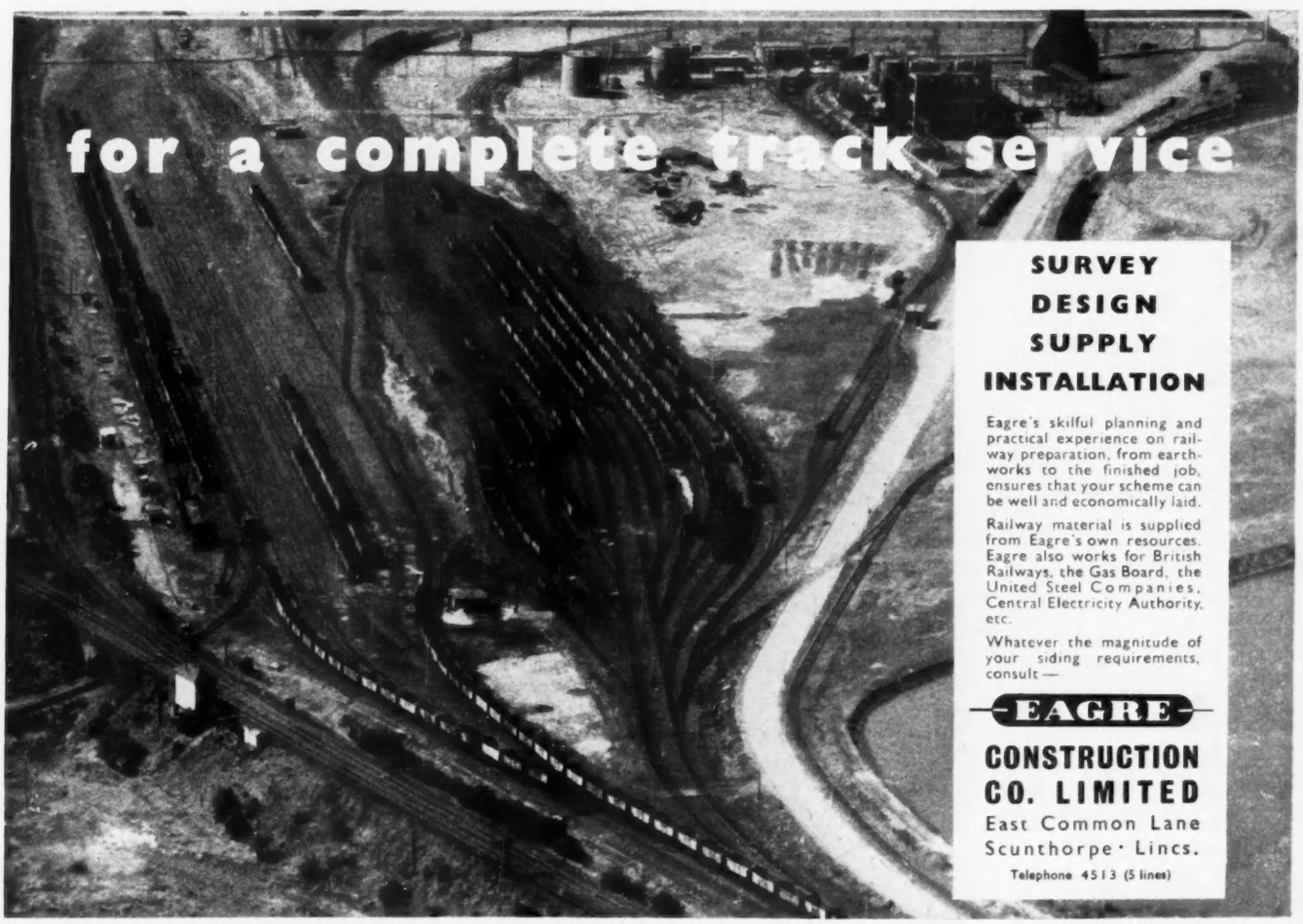
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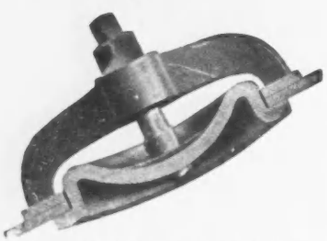

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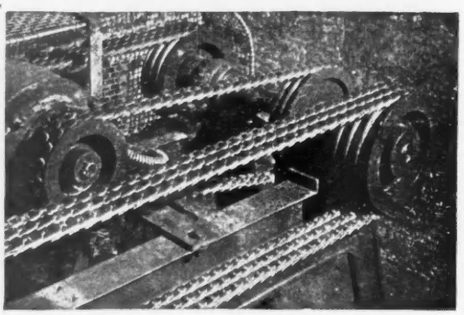

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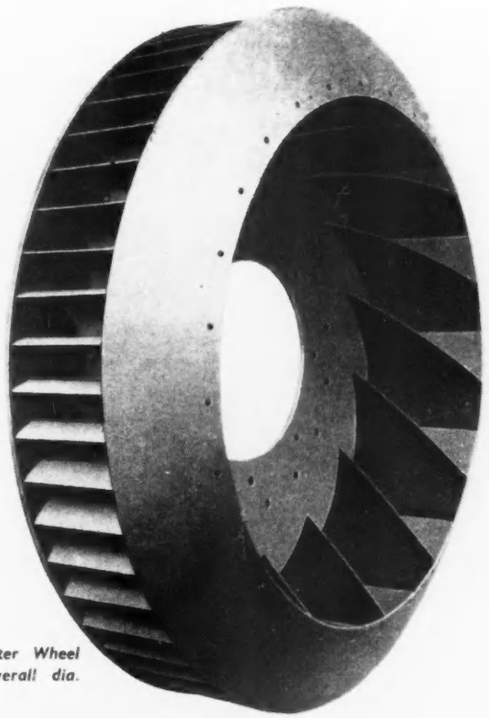

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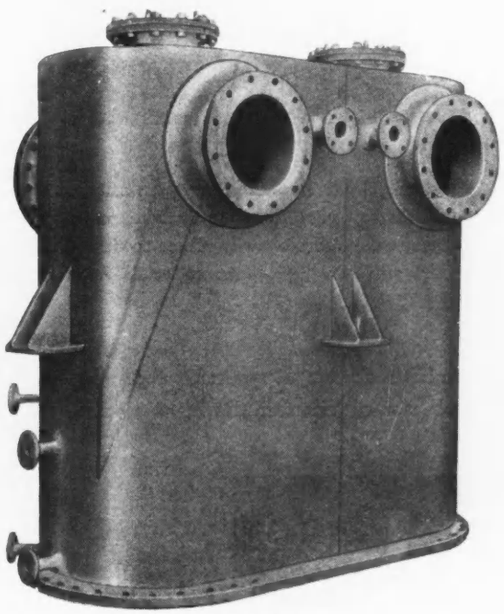

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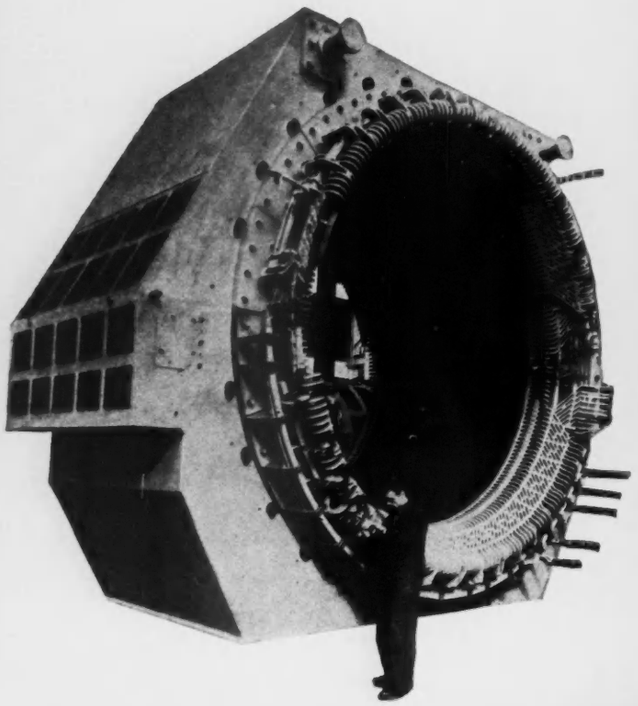

The stator of the 60MW hydro-alternator at Aura Power Station, Norway.

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Norway is another of the water-lands. Here, deep in the mountainside at the head of the Sunndalsfjord is the Aura Power Station. And here a 60MW hydro-alternator has been installed for the Norwegian State Power Company by the G.E.C. In Tasmania, too, the G.E.C. has recently installed five 25MW hydro-alternators at Tungatinah.

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Three 25MW vertical-shaft alternators at Errochty Power Station, Scotland.

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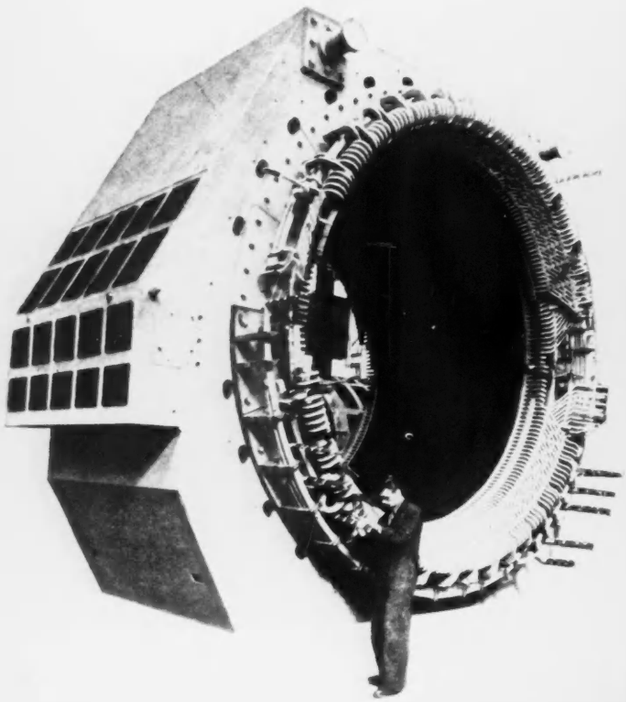

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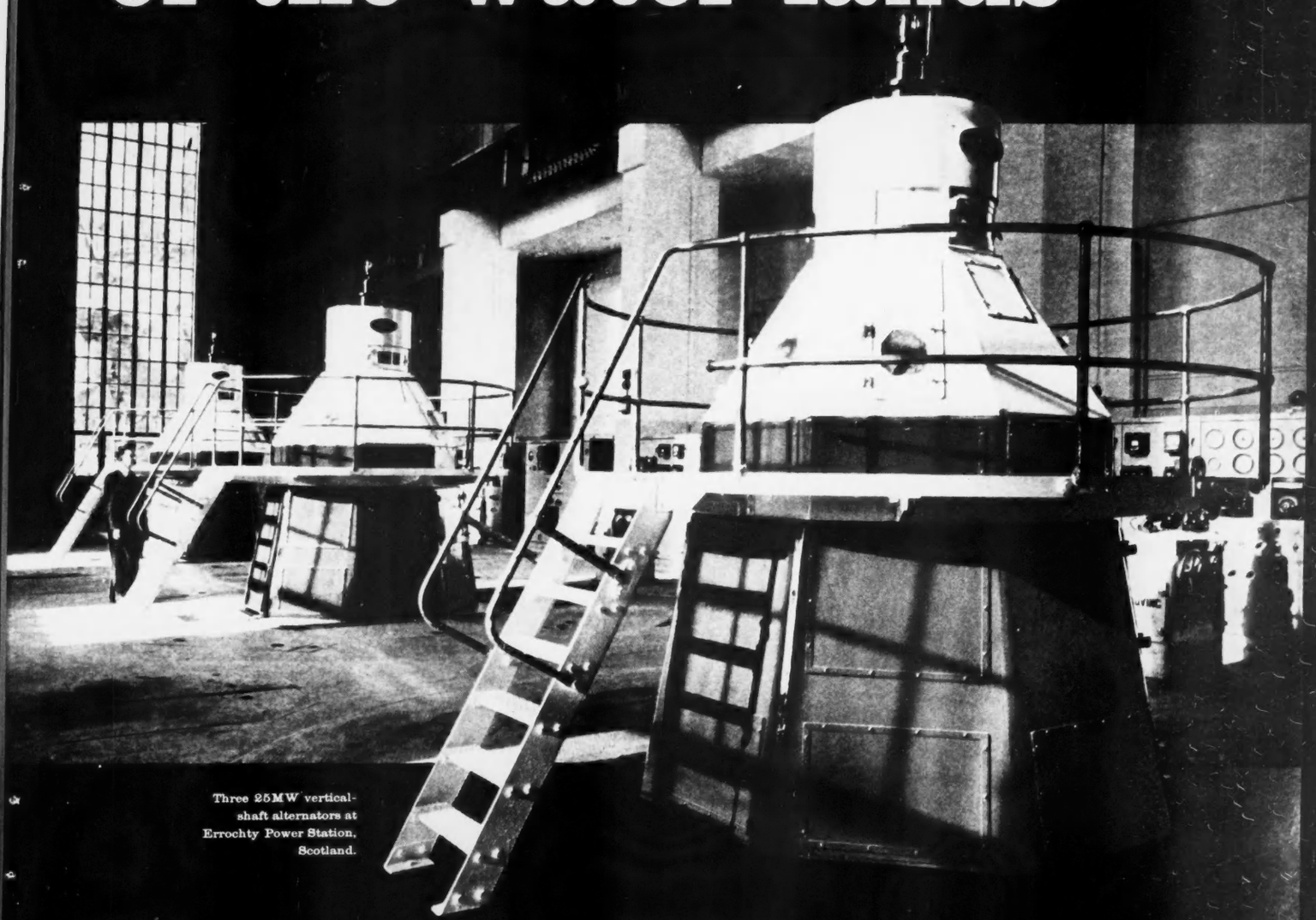

Three 25MW vertical-shaft alternators at Errochty Power Station, Scotland.

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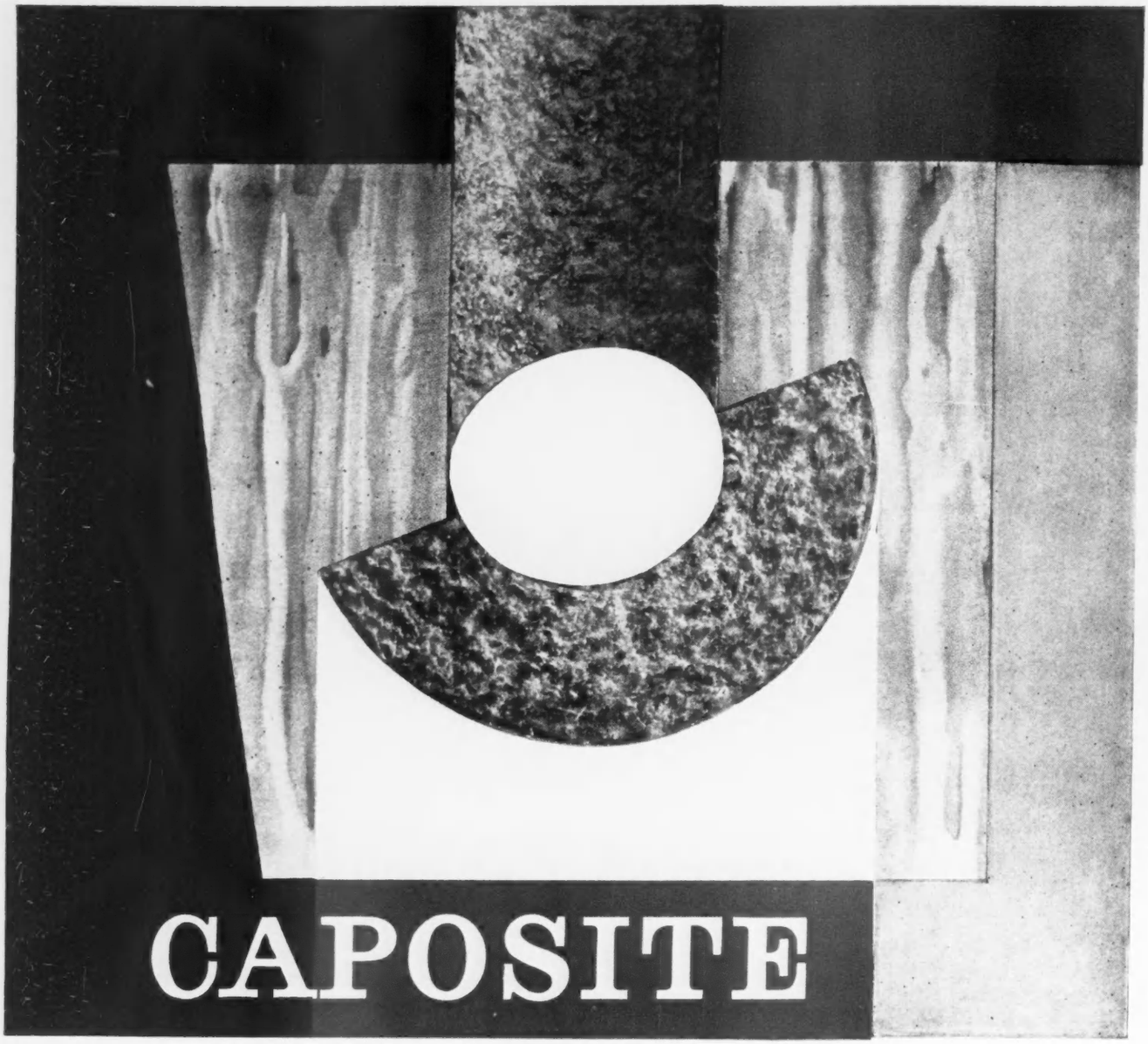

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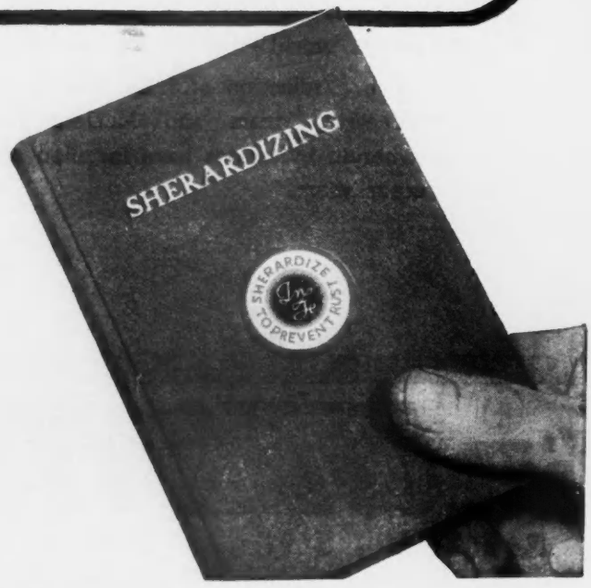

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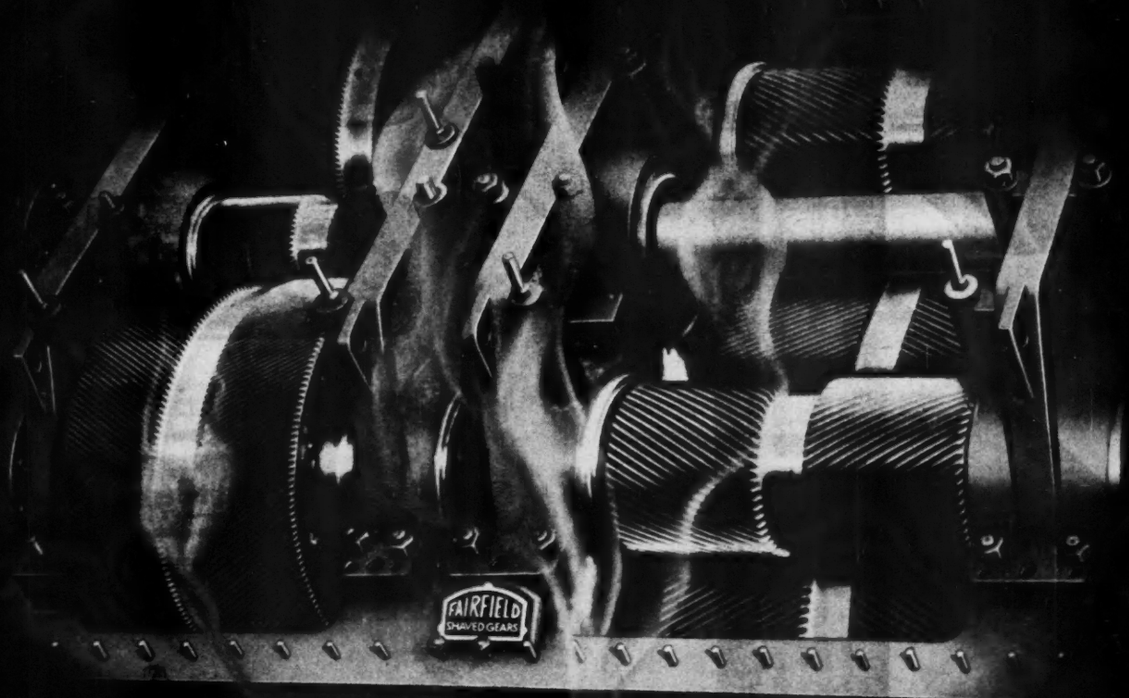

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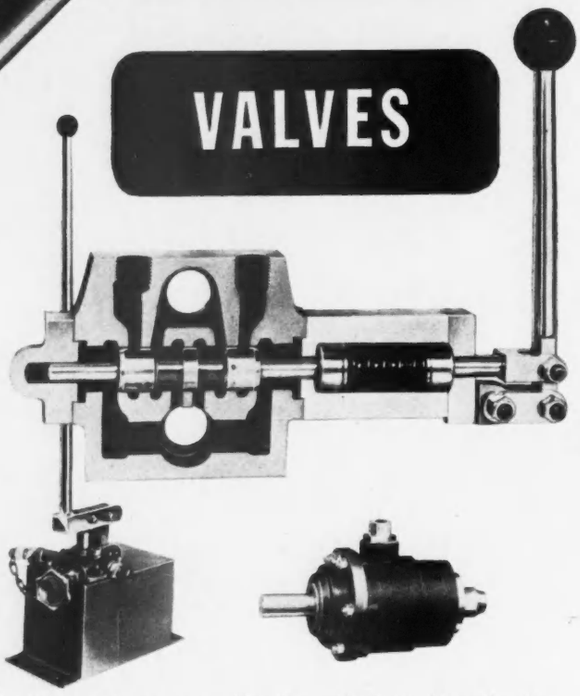

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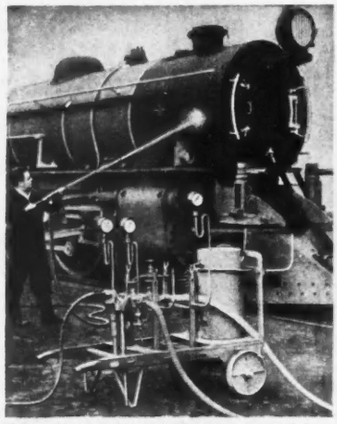
The "Metcalfe's" High Pressure Washing Plant provides the answer to the problem of cleaning in industry to-day. The plant is supplied on a suitable hand truck for portable use or it can be fitted as a permanent installation, and the only services required to operate it are :

(1) Water supply (static or mains). The consumption is 550 gallons per hour.

(2) Steam supply at any pressure above 60lbs. per square inch. The consumption is 700lbs. per hour.

The Washer is extremely simple to operate and can be easily operated in complete safety by unskilled personnel. The high temperature and pressure of the jet make it unequalled for power and efficiency and the use of cleaning solutions is not normally required.



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CLEANING A LOCOMOTIVE

CLEANING A SLAUGHTER-HOUSE FLOOR

ADVANTAGES OF THE 'D & M' SYSTEM OF WASHING

- (1) Delivers an extremely hot supply of water at a very high pressure thus ensuring the most efficient cleaning.
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- (3) The injector is perfectly automatic and re-starting and requires no attention once the water valve has been set for the usual working pressures.
- (4) It will operate satisfactorily with low steam pressures (60lbs. per square inch upwards).
- (5) It can be operated with perfect safety and satisfaction by a non-skilled labourer.
- (6) Simple, compact and light.
- (7) No detergents or cleaning solutions are normally necessary.
- (8) No other system offers the same flexibility at low operating costs, low maintenance and low installation costs as the Metcalfe High Pressure Washing Plant.
- (9) A wide range of jet temperature and pressure is available so that the apparatus is suitable for all types of requirements.

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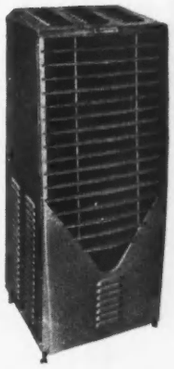

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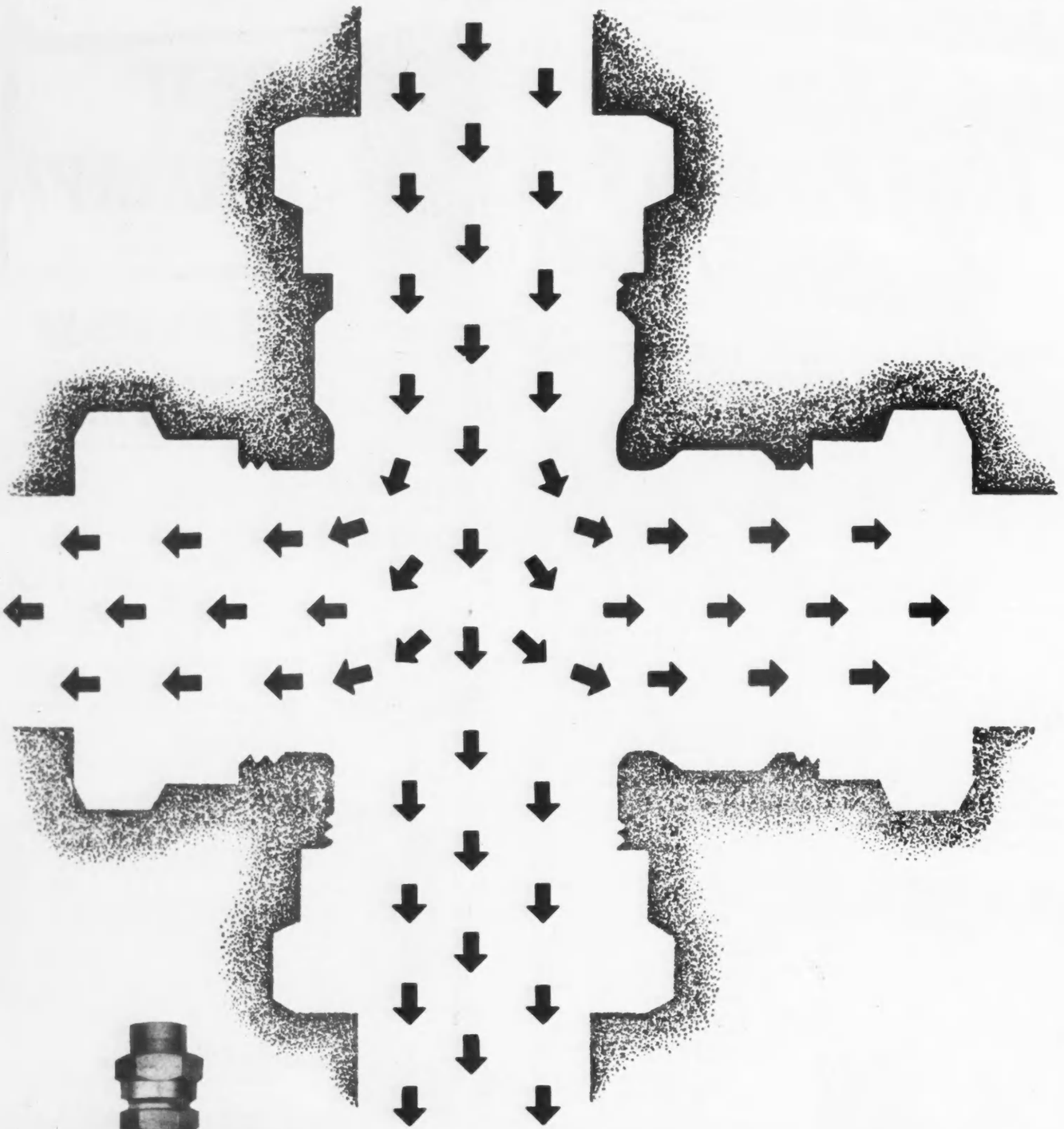

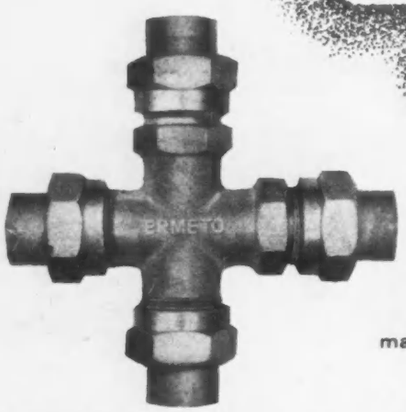

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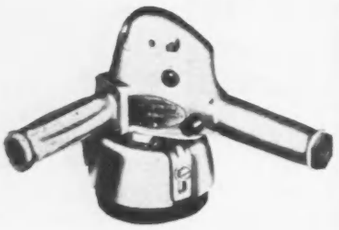

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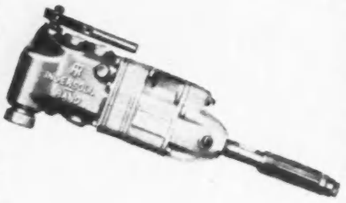

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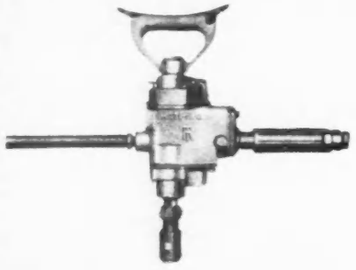

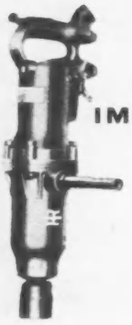

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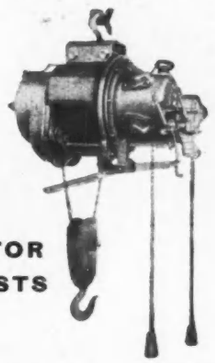

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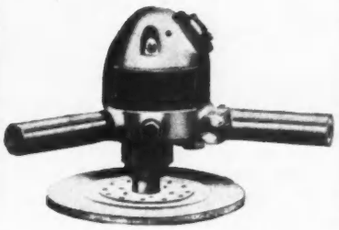

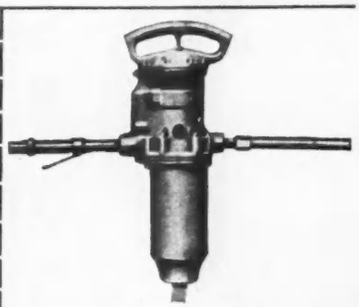

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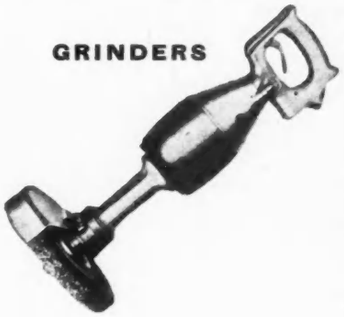

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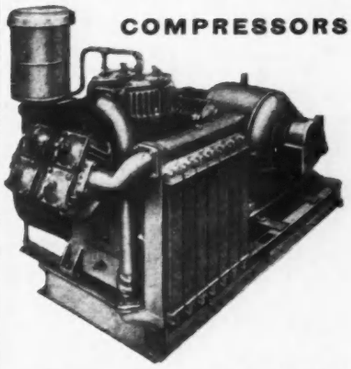

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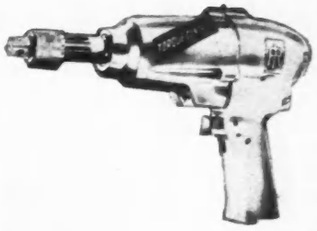

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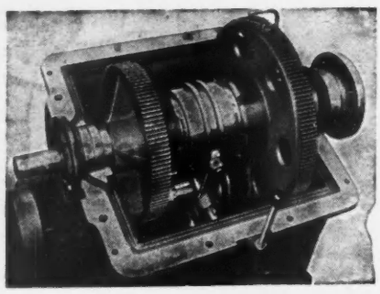

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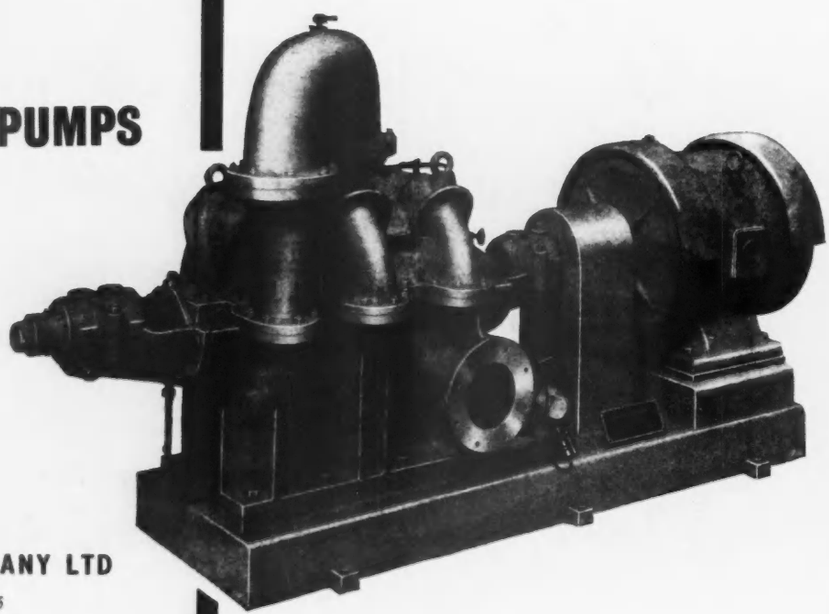

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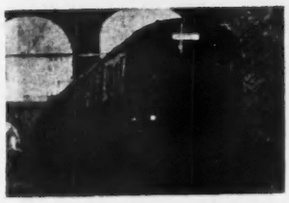
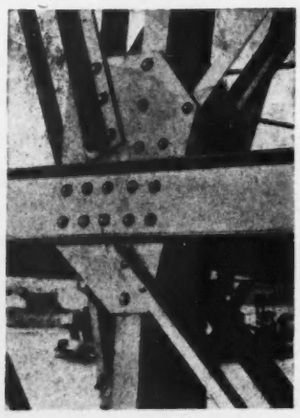

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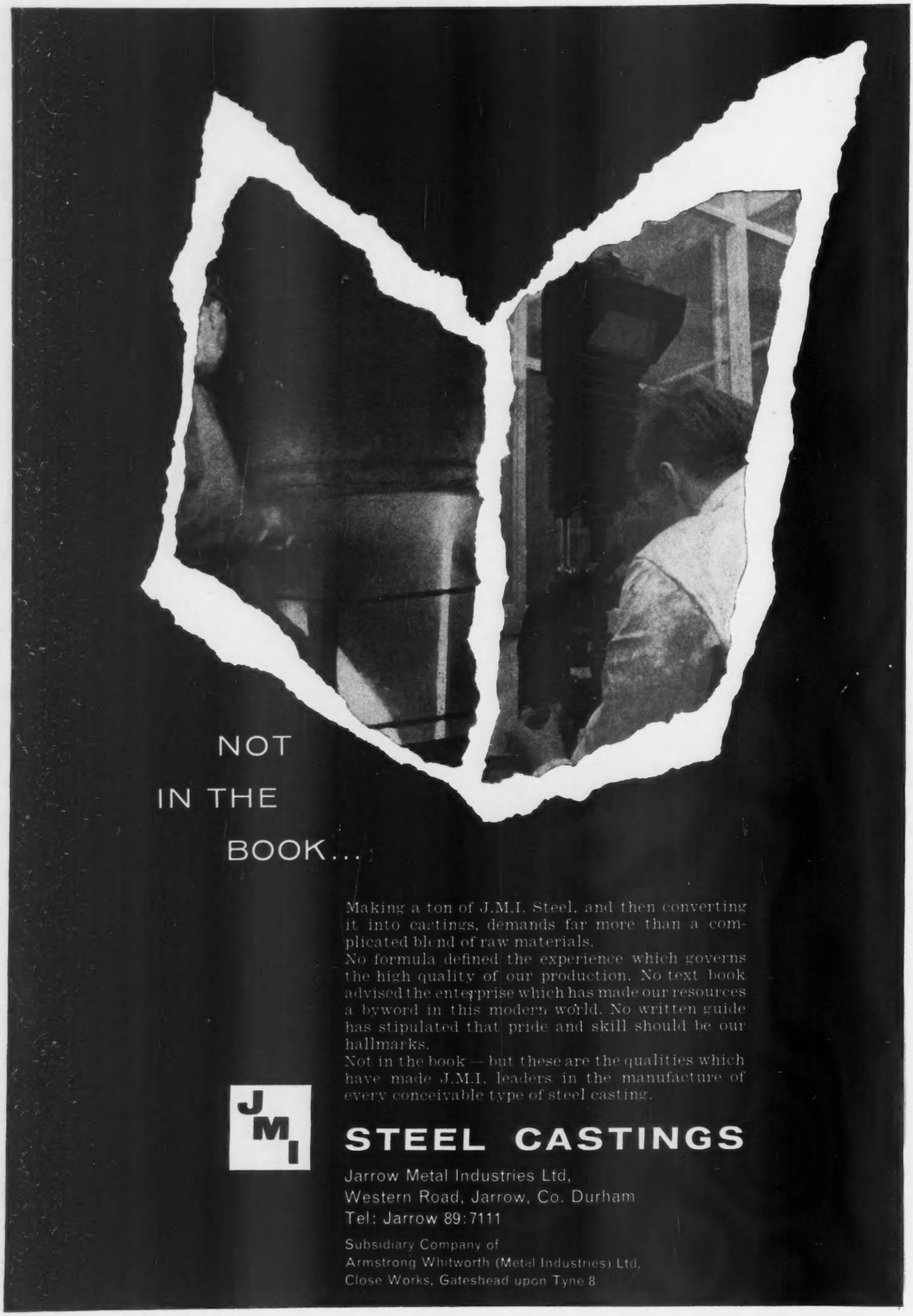
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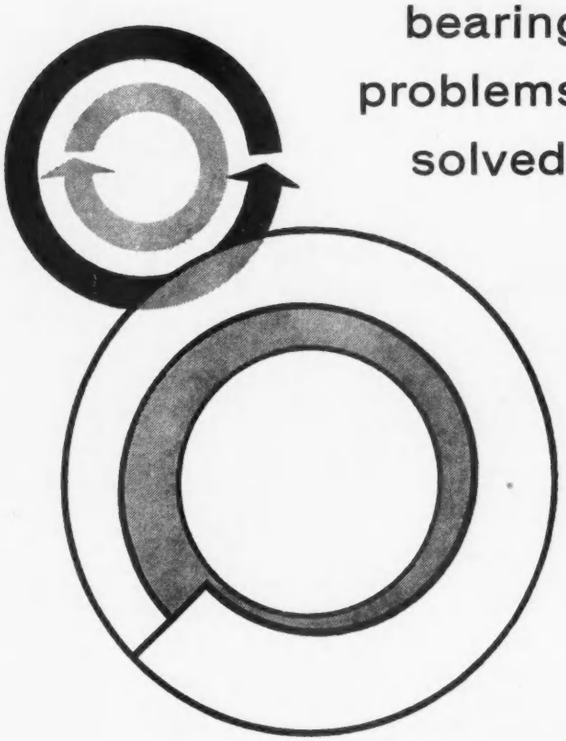

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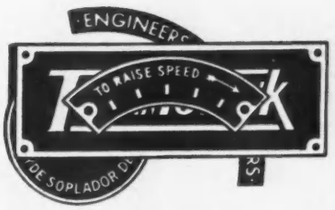

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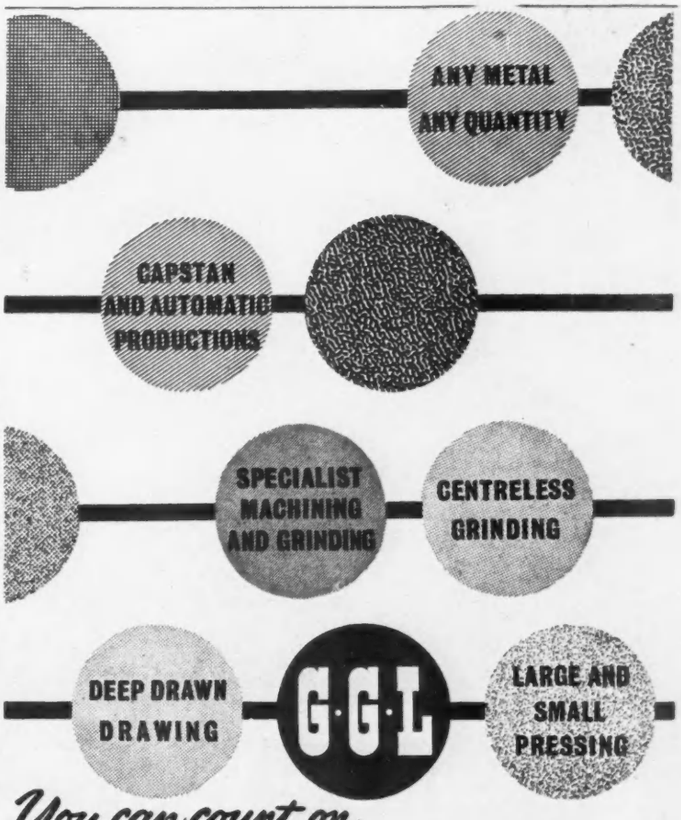

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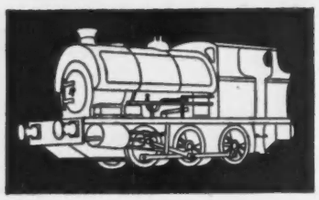

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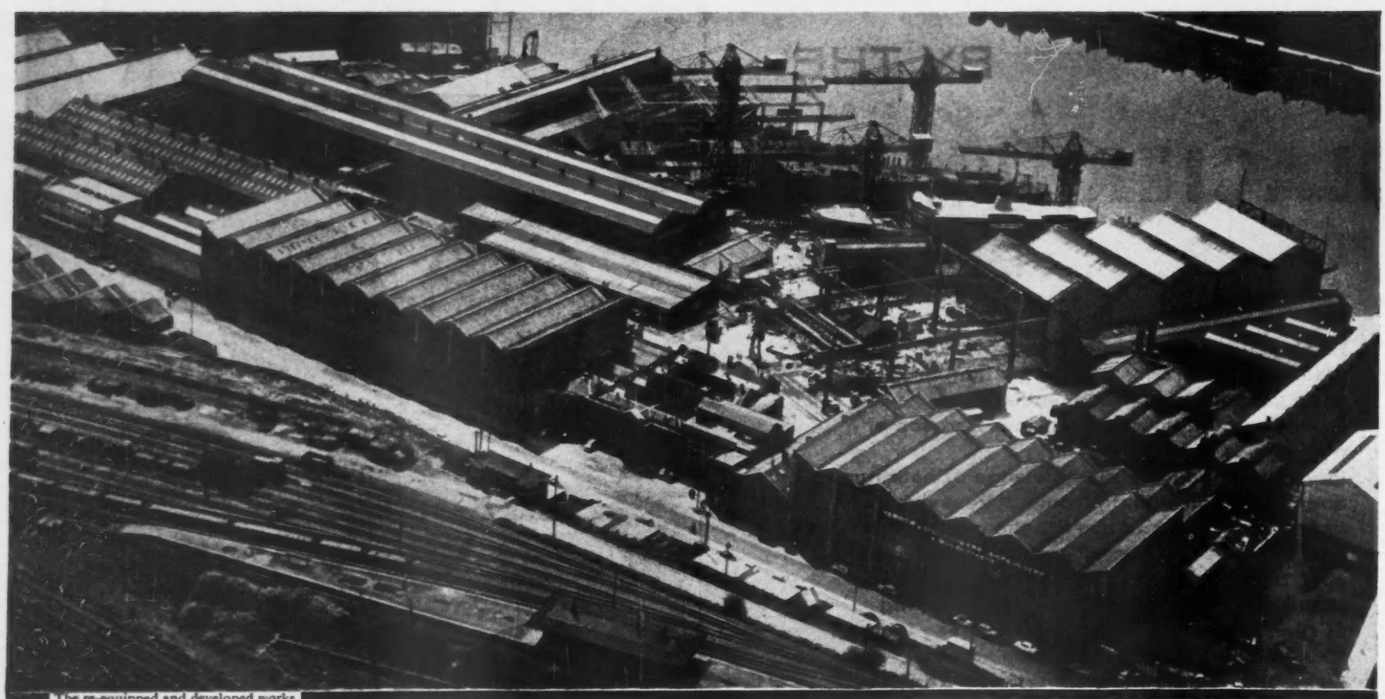

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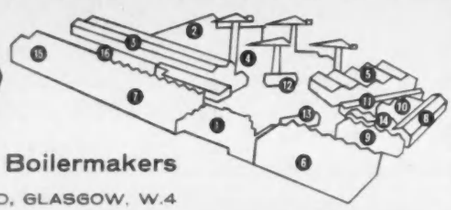

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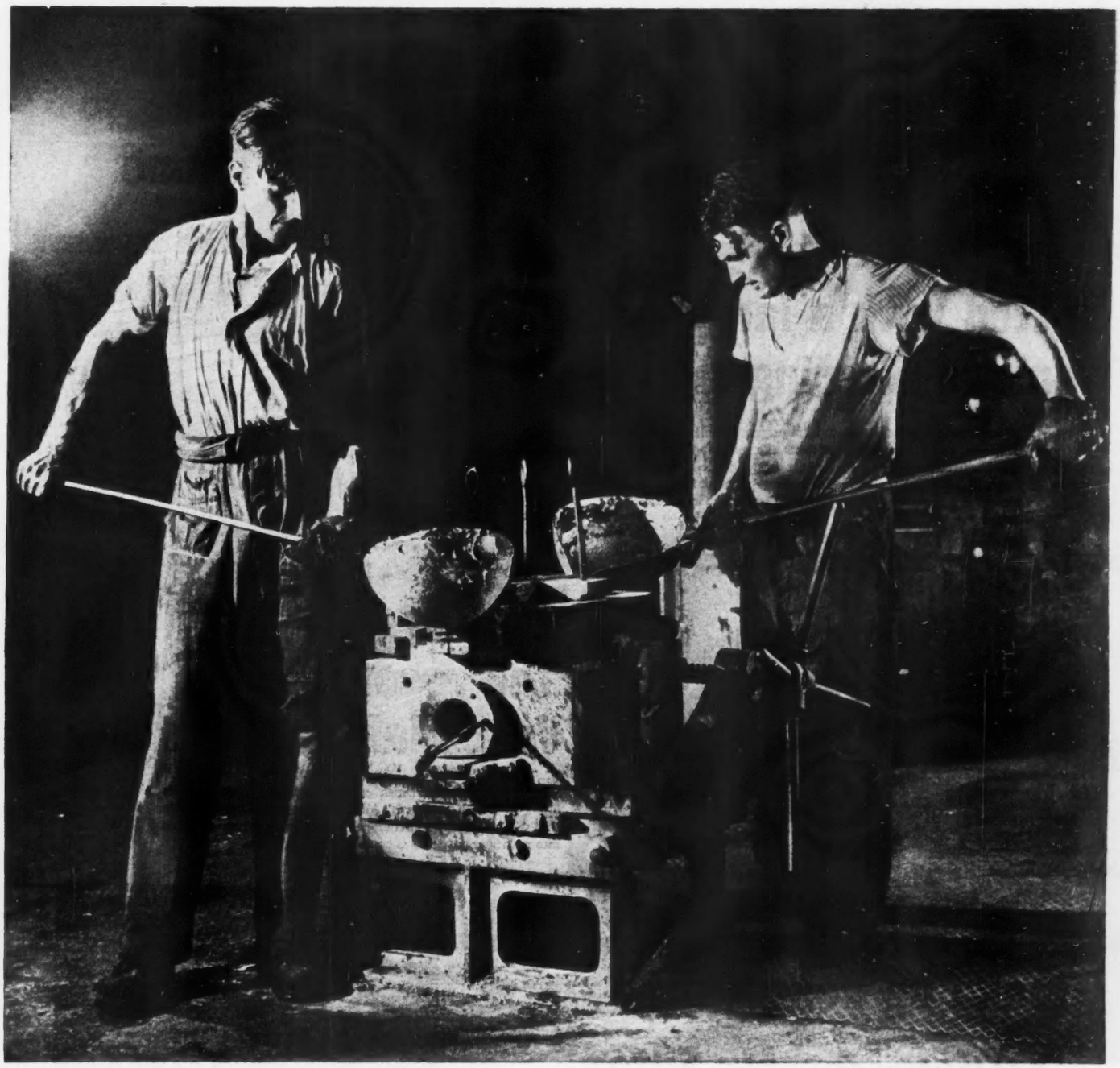

Strictly to Specification

The selection of alloy for a given casting is influenced by design and foundry technique as well as by the physical properties required of the casting in service. Close co-operation between designer and founder is therefore desirable to determine the most suitable alloys and this must be effectively supported by regular checks of incoming materials and foundry melts to ensure conformity to specification.

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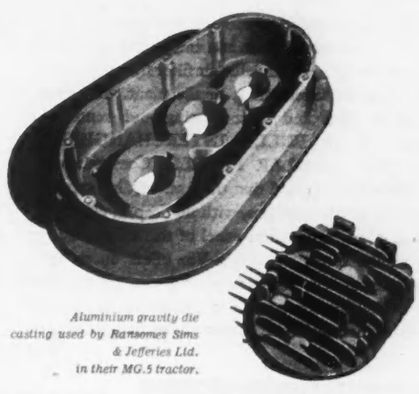

Aluminium gravity die casting used by Ransomes Sims & Jefferies Ltd. in their MG.5 tractor.

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AP118

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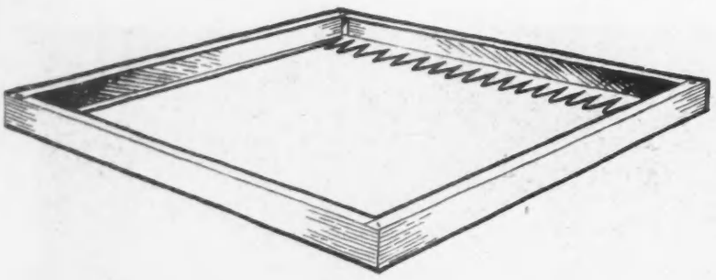
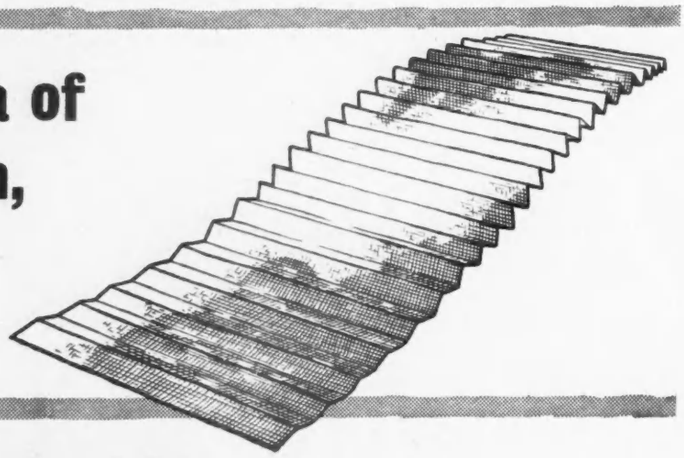
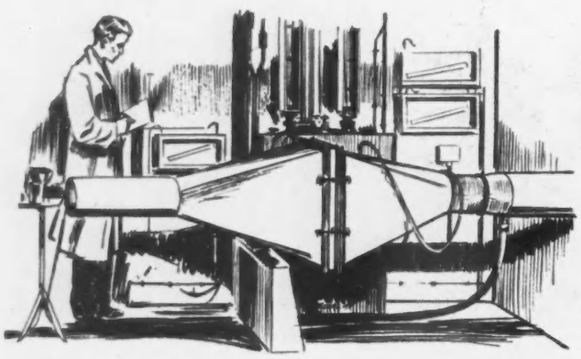


A low-cost expendable frame

fitted with a large area of unique filtering medium,

The synthetic fibrous medium is impregnated with a newly developed adhesive which adds to its efficiency and effective life. Unaffected by moisture, non-cracking, and free from fibre migration, the medium is supplied in flame-resistant form. It is pleated to present the greatest possible filter surface in the most compact space.



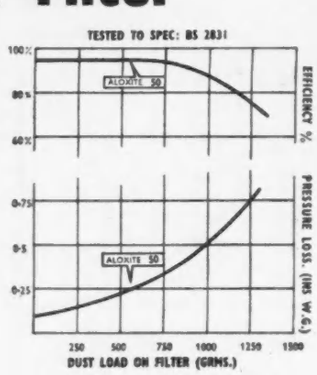


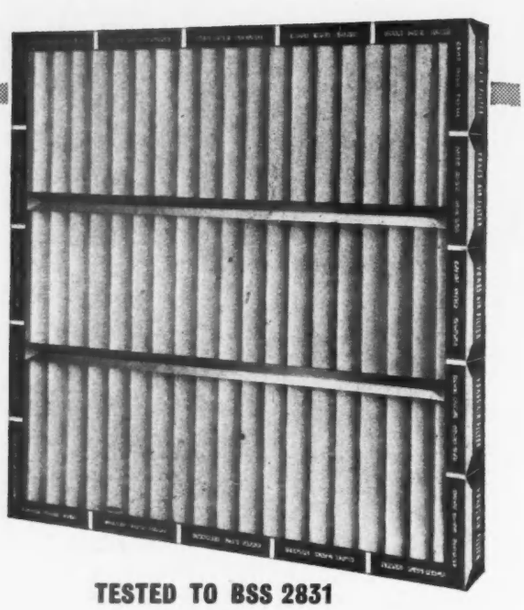
backed by all the resources of Vokes laboratories,

Vokes is an entirely British company and therefore tests its filters to British standards. All Vokes air filters are tested to BSS 2831 in their well-equipped laboratories, where research into new filter materials is continuously carried on.

make up Vokes new *Super-Vee** Air Filter

Vokes Super-Vee Air Filter with its sustained efficiency under severe industrial pollution and smog conditions is the best low cost, long life, expendable air filter for paint finishing plant, chemical laboratories, textile plant, distilleries, nuclear power plant and most heating and ventilating applications. IT IS FULLY INTERCHANGEABLE WITH OTHER SIMILAR PANELS. Comprehensive testing to BSS 2831 showed that the dust-holding capacity for a given rise in pressure loss, with no drop in efficiency, exceeds that of any other filter panel of this class. Size for size with similar filters the Super-Vee offers up to 25% greater capacity thereby considerably reducing the number of panels needed for any particular application, allowing a more compact installation *and* lower maintenance costs.





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* *Registered Trade Name*
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Represented throughout the world

V503

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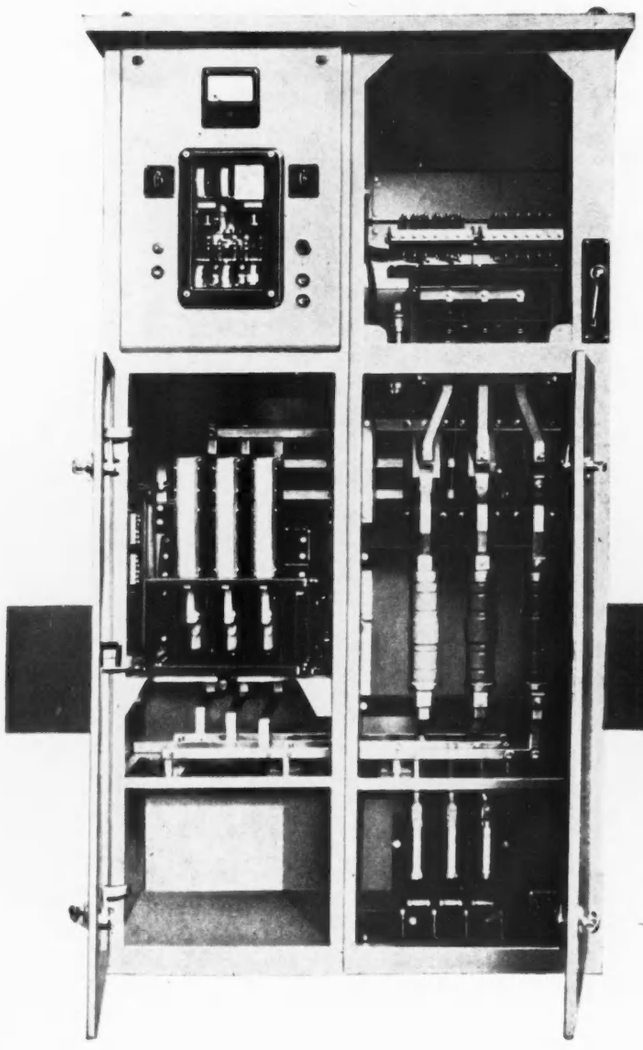
THE BELMOS 3·3 kV AIR-BREAK CONTACTOR STARTER



Rigorously tested in the Company's own research laboratory, the type K contactor starter is the latest product of the Belmos development team and continues the well-established Belmos tradition of good design and reliability. Suitable for the direct-on-line starting of 3·3 kV motors up to 600 h.p., it can be housed in a free-standing pillar or grouped with similar units to form a switchboard.

- ★ Air-break contactor rated at 150 amperes. Breaking capacity of 1,300 amperes at 3·3 kV, 0·25 power factor.
- ★ DC operating magnet supplied from 3,300/110 volt transformer within the pillar.
- ★ Reversing or Earthing isolator, mechanically and electrically interlocked, with 12 auxiliary switches, AC or DC.
- ★ Busbars designed to withstand 150 MVA for 3 seconds.
- ★ Optional earth leakage protection.
- ★ Comprehensive control arrangements, local and remote, with sequence interlocking and automatic sequence starting.
- ★ Provision for auxiliary services, such as brake protection, local lighting, etc.

the type K starter is fully described and illustrated in leaflet J 240 which is available on request.

Belmos

the Belmos company limited

BELLSHILL · LANARKSHIRE

LONDON GLASGOW BIRMINGHAM NEWCASTLE MANCHESTER SHEFFIELD CARDIFF

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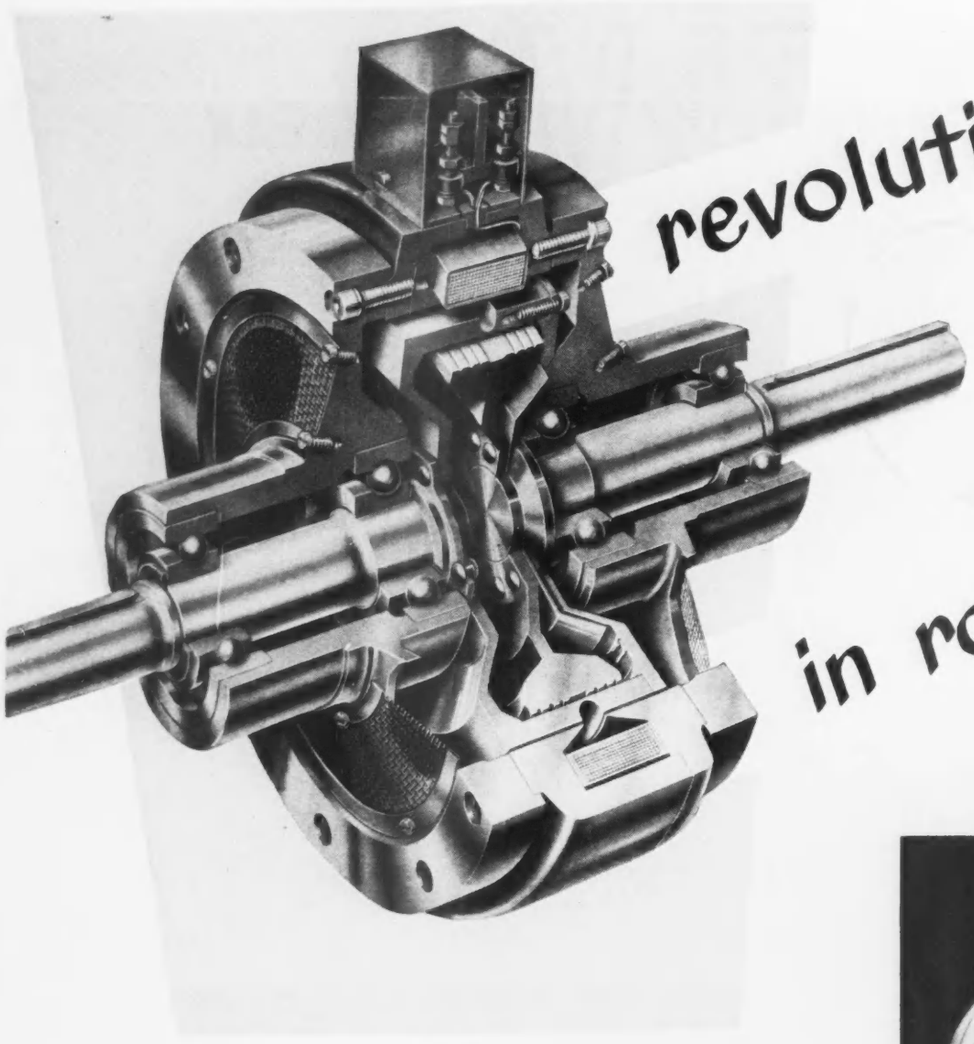
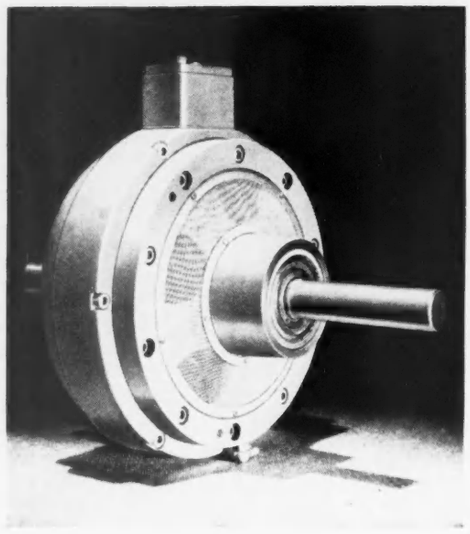


revolution in rotation

SMITHS
Magnetic Particle COUPLING

This is a positive coupling working on a new principle. It is NOT a magnetically operated clutch, and there are no plates to wear.



Driving and driven members are coupled by magnetically activated particles, giving perfectly smooth take-up and accurate control of torque. Eight standard units are made ranging from 1/3 to 200 lb/ft.

SMITHS S. SMITH & SONS (ENGLAND) LIMITED

INDUSTRIAL PRODUCTS DEPARTMENT, WITNEY, OXON · Telephone: WITNEY 678

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FOR ALL BULK MATERIAL

NEW

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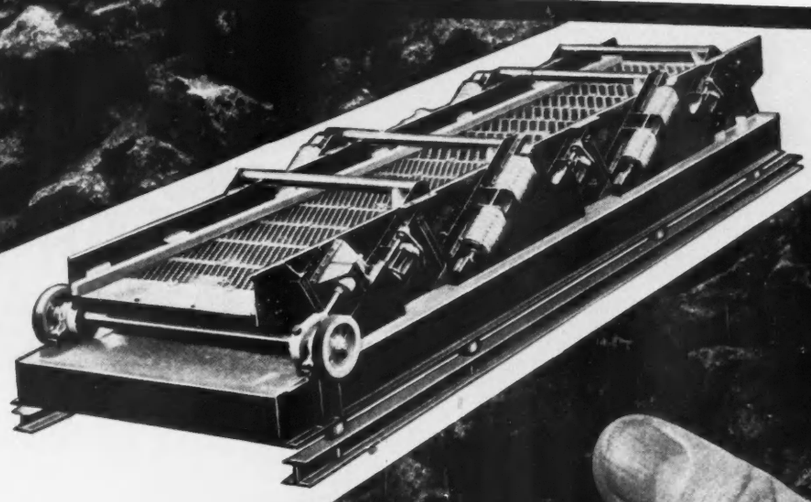

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SHEFFIELD 9

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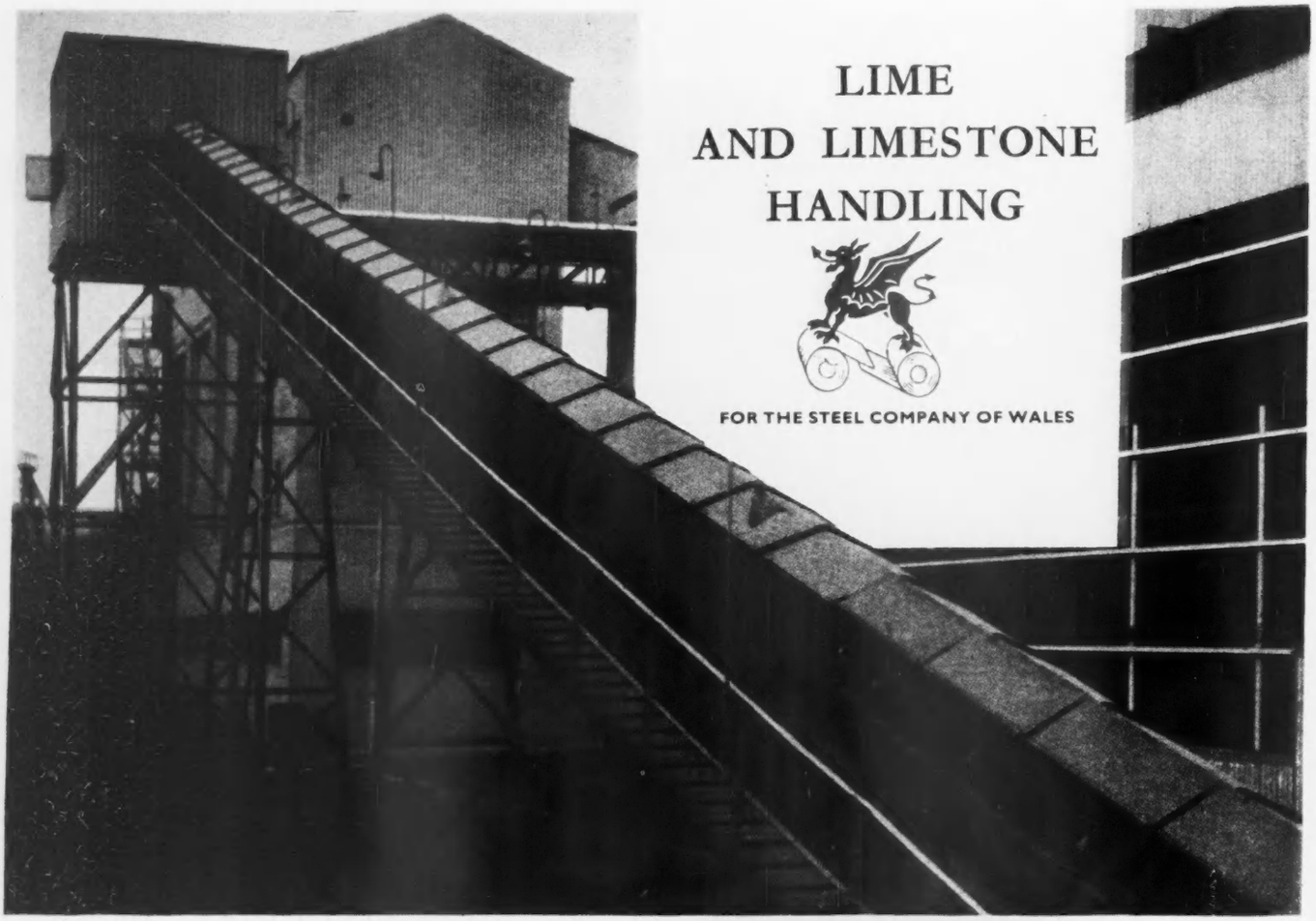

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FOR THE STEEL COMPANY OF WALES

Another important contribution by

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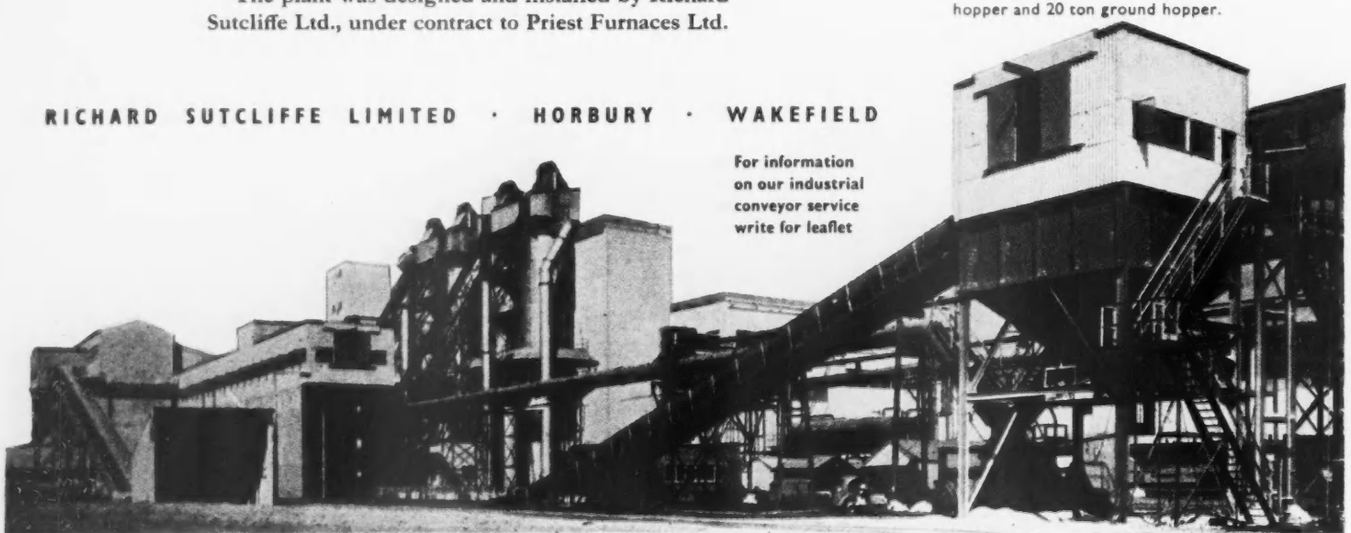
Limestone is fed from lorries into a 20 ton ground hopper. The limestone is then raised by a 30″ Sutcliffe belt conveyor to the main storage bunkers. Fines from the feeders are collected by a 24″ Sutcliffe conveyor and returned to the rejects bunkers. Another 24″ conveyor delivers lump lime from the kilns onto a skip hoist for screening. The plant was designed and installed by Richard Sutcliffe Ltd., under contract to Priest Furnaces Ltd.

Above: Main conveyor to the limestone holding bunkers.

Below: Photograph showing the complete layout of the Plant including the limestone rejection hopper and 20 ton ground hopper.

RICHARD SUTCLIFFE LIMITED · HORBURY · WAKEFIELD

For information on our industrial conveyor service write for leaflet



RS 69

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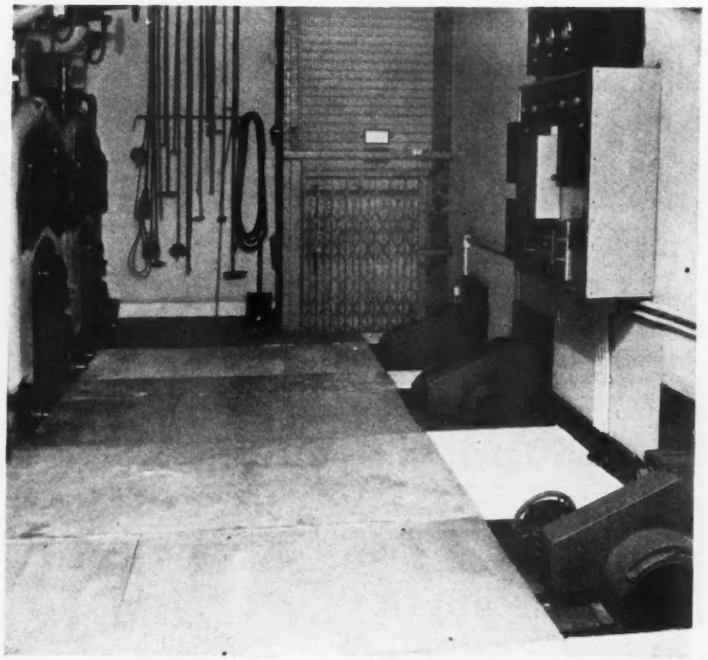

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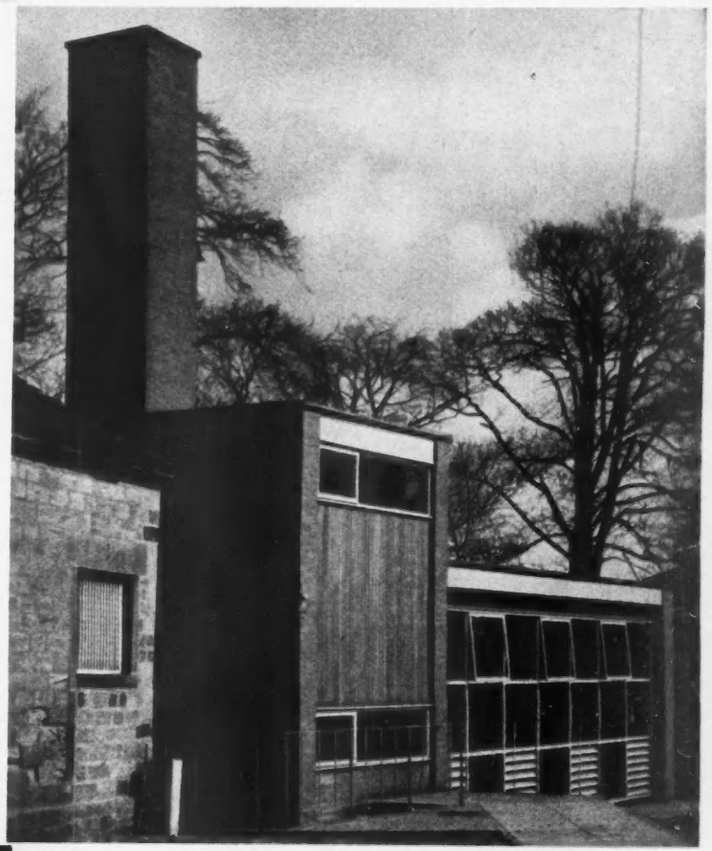
We have developed new techniques for ensuring smokeless combustion without the use of expensive fuels. Iron Firemen Stokers are meeting the requirements of the Clean Air Act* in the great majority of our industrial centres.

There is a model for every type and size of boiler from 200,000 to 9,000,000 B.T.U.s per hour capacity and we have a nation-wide organisation for the service and maintenance of our machines.

** Boilers and furnaces fired by mechanical stokers are now an exempted class of appliance under the recent order made by the Ministry.*



Iron Fireman

"FIRST AND FOREMOST"

Automatic Coal Stokers

Smokeless combustion means fuel economy

ASHWELL & NESBIT LTD. Barkby Road, Leicester

Branches at: LONDON, BIRMINGHAM, MANCHESTER, LEEDS, GLASGOW & BELFAST

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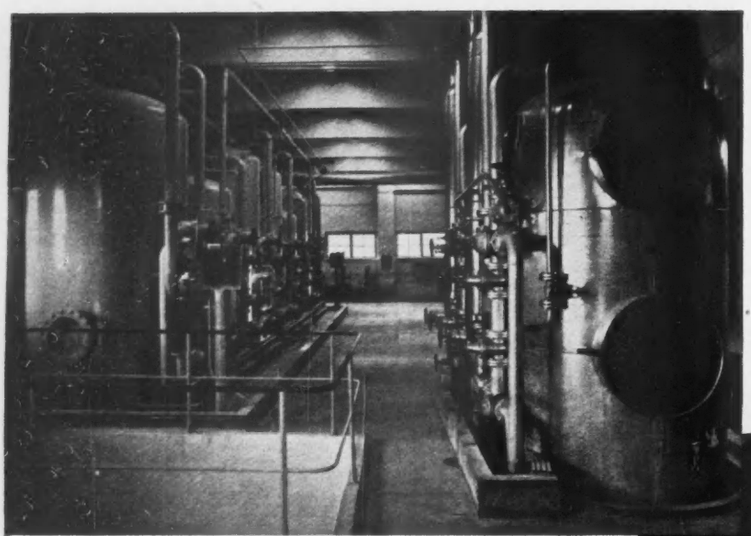
WATER TREATMENT IN FINLAND

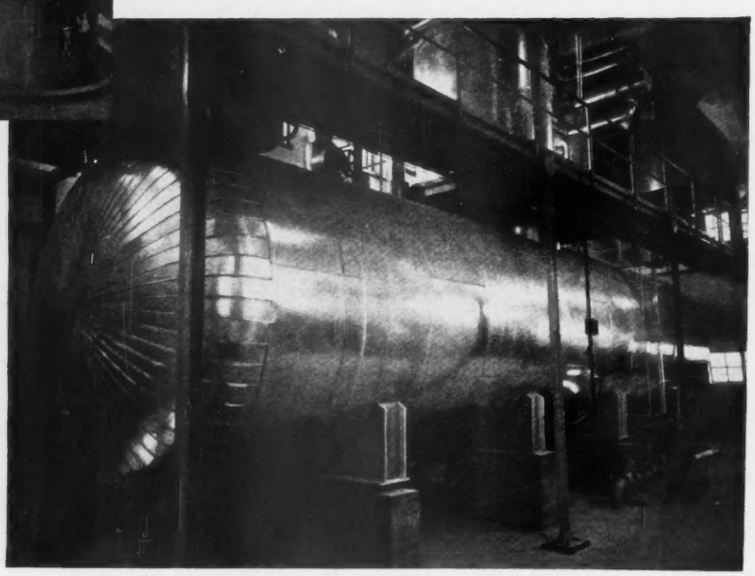
Complete boiler-feed water-treatment plant for the new Veitsiluoto O/Y Paper Mills, Finland

Boiler pressure 1,750 psi, 42% make-up



One of seven similar "Boby" installations in Finland treating highly organic lake-water for boiler feed purposes.
All plant made in Finland to the designs of William Boby & Co.

Demineralisation Plant for Boiler feed make-up, capacity 13,400 g.p.h. and base-exchange softener for condensate returns, capacity 18,000 g.p.h.



Deaeration Plant, capacity 250,000 p.p.h. with 30 minutes storage.

WATER BOBY TREATMENT

Established in 1875

WILLIAM BOBY & CO. LTD.

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AIR OPERATED PUMPS & MOTORS

Pumps are made in a wide variety of materials to cope with all liquids. Neumo motors containing only two moving parts are a safe, reliable means of obtaining reciprocating motion and again may be stalled without damage.

Many industrial users are finding that control of liquid flow by means of a simple valve in the delivery line is all that is required when using Neumo positive displacement air operated pumps. This valve may be at any distance from the pump enabling operators to control pumps at distant points of delivery.
The system is reliable because no extra control gear is employed, the pump merely stalling by back pressure in the delivery line and recommencing delivery upon release of the pressure. The possibility of raising undue pressure in the line is avoided by automatic over-load devices in the pump which can be set to come into action at a predetermined pressure.

Write for further details to:

NEUMO LIMITED
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Telephone: Peacehaven 2115 & 3354

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For Engineering and all Kindred Trades

ANY SIZE - ANY SHAPE

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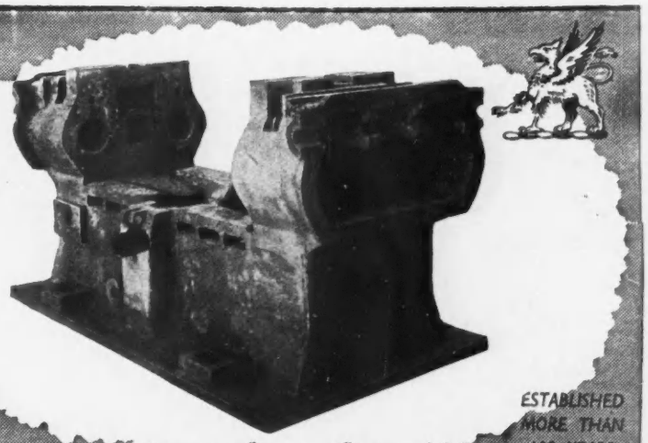

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Near BIRMINGHAM
Telephone: BROADWELL 1101 & 1102 Telegrams: GRIFFIN, OLDBURY

ESTABLISHED MORE THAN 100 YEARS

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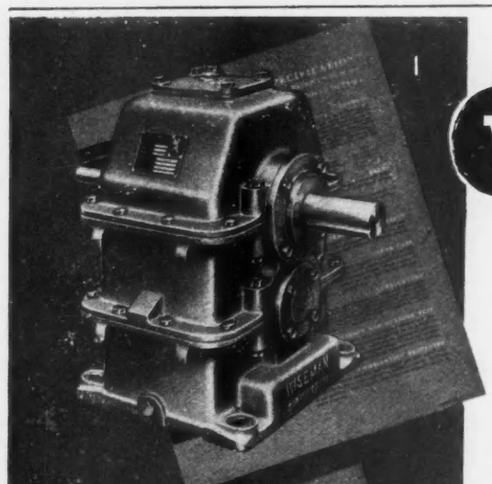
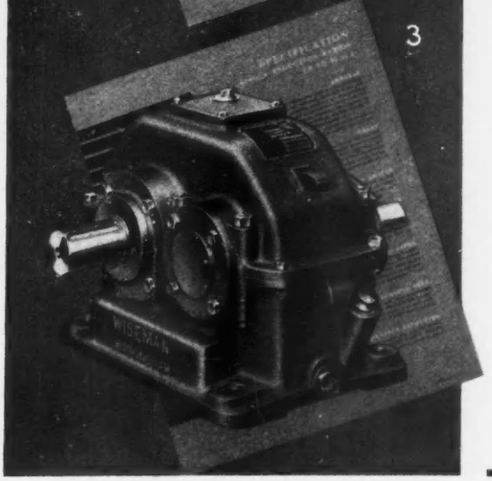
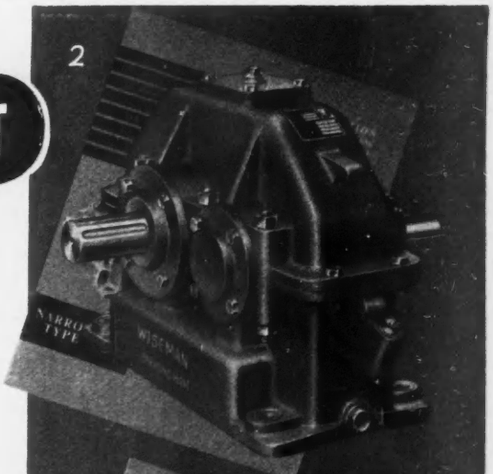
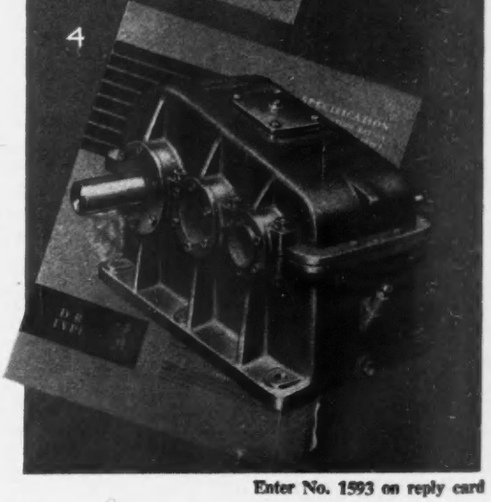
on

Totally enclosed, spur or helical gear units for industrial drives









(1) LEAFLET GB53
Co-axial type spur or helical gear units. Types DRCO and DRCV. Double reduction ratios up to 50 to 1. Single reduction ratios up to 7½ to 1.

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Single reduction spur or helical gear units. Type SR-N, narrow Ratios up to 5 and 10 to 1.

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Single reduction spur or helical gear units. Type SR-W wide. Ratios up to 5½ to 1.

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Double reduction spur or helical gear units. Type DR horizontal. Ratios up to 60 to 1.

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London Office: **8 Southampton Row, W.C.1**

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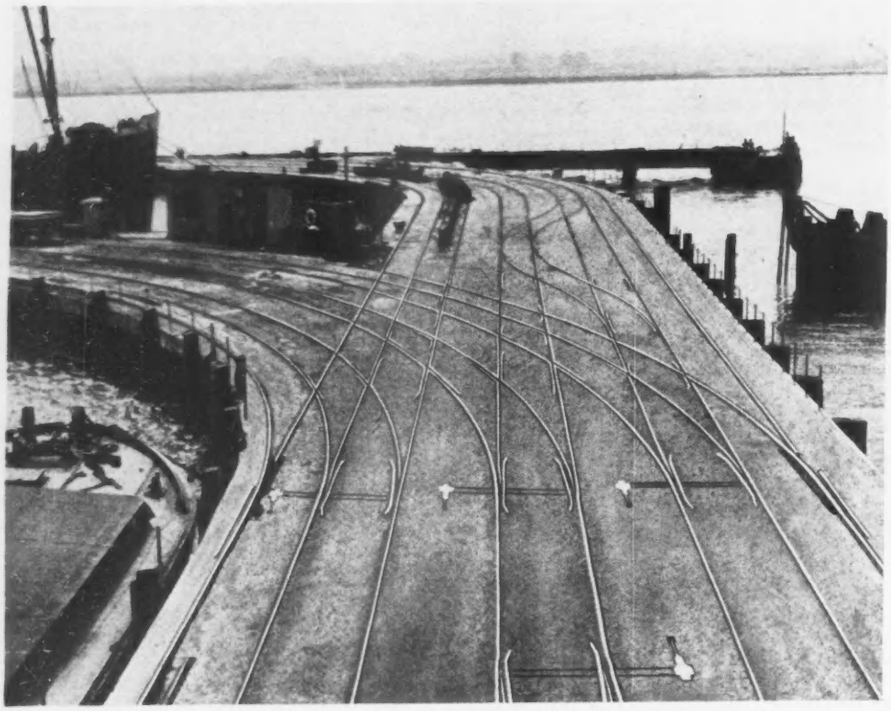
JETTY TRACKS BY SUMMERSON'S

Main Contractors: J. L. Kier & Co. Limited Monberg & Thorsen A.S
Consulting Engineers: Sir Alexander Gibb & Partners



This installation for the Tunnel Portland Cement Company, involved the manufacturing and laying of rail and crane tracks along the new jetty and joining up to existing tracks on the old jetty.
The tracks are 75 lb. F.B.B.S. ' R ' and 98 lb. F.B.B. Railways section.
The combination joining the new and old jetties to the main access tracks is a treble junction and Goliath crane track comprising three turnouts, three diamond crossings and thirteen crane crossings, all prefabricated and laid down as a unit at our Works to ensure the minimum disruption to traffic. In addition, six throughroads were manufactured and installed as well as 1,053 yards of straight and curved crane and rail track, most of the crane track angle guarded.
This is yet another example of Summerson's resources and 120 years' experience in the design, manufacture and laying of railway sidings.
Always consult Summerson first on railway siding problems.

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MOWDEN HALL, DARLINGTON Darlington 5226
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Up to £25 tax-free Bonus plus first-rate wages for two weeks of your time

ARE you in a skilled trade? Then you can probably add a tidy sum to your income by joining the Army Emergency Reserve. For one thing, you get pay and allowances at full Regular Army rates whilst in camp. And the more your skill is worth in civilian life, the higher your Army trade pay will be. Better still, you also get £9-£25 bonus tax-free.
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Copy Dates. "Run-on" and "Semi-displayed" advertisements by noon Tuesday for publication on Friday same week. "Displayed" and "Illustrated" advertisements by noon Friday for publication on following Friday. All advertisements three days earlier if proofs are required.

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Urgent advertisements may be telephoned to CENtral 6565

PUBLIC APPOINTMENTS

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(FACULTY OF TECHNOLOGY IN THE UNIVERSITY OF MANCHESTER)

APPOINTMENT OF

LECTURER OR ASSISTANT LECTURER IN MECHANICAL ENGINEERING

The Governing Body invites applications for a LECTURESHIP OR ASSISTANT LECTURESHIP IN MECHANICAL ENGINEERING in The Manchester College of Science and Technology, with corresponding title and status in the University of Manchester.

The Department covers a very wide field in Mechanical Engineering, including Photo-elasticity, Fatigue, Servo-mechanisms, Vibrations, Machine Tools and Production Processes and Heat Transfer. A special high level Diploma Course in Machine Tool Design lasting two years has just been inaugurated. All members of staff are expected to undertake, assist in or supervise research in their particular subject, for which facilities are excellent. The teaching is almost entirely confined to Graduate and Post Graduate Courses for Internal Degrees and Diplomas. Short courses for specialists in subjects of particular interest are offered each year.

Salary: Lecturer: £900 by £50 to £1350 by £75 to £1650. Assistant Lecturer: £700 by £50 to £850.

Commencing salary according to qualifications and experience. F.S.S.U. and family allowances.

Conditions of appointment and form of application may be obtained from the Registrar, The Manchester College of Science and Technology, Manchester, 1. The last day for the receipt of applications is Saturday, 12th December, 1959. E7998

UNIVERSITY OF BIRMINGHAM

DEPARTMENT OF MECHANICAL ENGINEERING

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Applications are invited from candidates possessing an Honours Degree in a branch of Engineering Physics or Mathematics for the following posts in the Department of Mechanical Engineering:

(1) LECTURER to teach DRAWING AND DESIGN. The successful candidate is intended to be the core of a design study team which, in addition to giving support to the general research of the Department, will work on special design problems of considerable complexity. Experience in design is necessary.

(2) LECTURER to teach THERMODYNAMICS. Previous experience in teaching and/or research in Thermodynamics, Dynamics or Metal Cutting is desirable.

The Department has exceptional facilities for research, and successful candidates for the above posts will be expected to make full use of these.

Each appointment will be made at an appropriate point, according to qualifications and experience, in the salary scale £900 by £50 to £1350; £1350 by £75 to £1650, with F.S.S.U. and family allowance benefits. Appointments will date from 1 January, 1960, or as soon as possible thereafter.

Applications (three copies) with the names of three referees, should be sent by 5 December, 1959, to the Deputy Registrar, The University, Edgbaston, Birmingham, 15, from whom further particulars can be obtained. E8037

CIVIL SERVICE COMMISSION

H.M. DOCKYARD TECHNICAL COLLEGES

ASSISTANT LECTURERS

ASSISTANT LECTURERS (Grade A or B). Pensionable (non-contributory) posts for men: two in Electrical Engineering (Portsmouth and Rosyth); one in Mechanical Engineering (Devonport); one in Naval Architecture (Portsmouth); one (Grade A only) in English with a modern language (Chatham). Ability to help with other subjects essential. Appointment January, 1960, or as soon after as possible. Qualifications: University degree or equivalent and ability to teach special subject to H.N.C. standard. Burnham scales for Technical Colleges. Write Civil Service Commission, Burlington Gardens, London, W.1, for application form quoting 5057/59. Closing date, 10th December, 1959. E7939

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VACANCIES EXIST FOR HOLDERS OF:

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(c) A.R.I.C.S. (Valuation) or A.A.I. (Urban) as VALUATION OFFICER. Salary: £624 to £1380 per annum.

(d) Degree or Diploma or Certificate in Social Science as CHIEF WELFARE OFFICER. Salary: £1500 to £1620 per annum.

(e) Honours Degree in Biology, Mathematics, Physics, Chemistry, Botany, Zoology, as EDUCATION OFFICERS. Salary: £690 to £1524 per annum.

(f) Certificate in Commercial Subjects, including Teachers' Certificate in Shorthand (Pitman's) and Typing from the Royal Society of Arts or any other recognised examining body as TRADE INSTRUCTRESSES IN COMMERCIAL SUBJECTS (Pitman's Shorthand and Typewriting inclusive). Contract salary: £630 to £1116 per annum.

All salaries are exclusive of inducement additions and other allowances. Starting point depends on qualifications and experience.

For further information, apply to:
Secretary to the Commissioner for Eastern Nigeria, 9, Northumberland Avenue, London, W.C.2. E8017

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VICTORIA INSTITUTE

ASSISTANT LECTURER (GRADE B)

Applications are invited for the appointment of ASSISTANT LECTURER (Grade B), to teach Electrical Engineering subjects up to Ordinary National Certificate standard. Duties to commence 1st January, 1960, if possible.

Salary scale: £700 to £1150 per annum.

Applicants should possess at least a Higher National Certificate in Electrical Engineering and teaching experience would be an added recommendation.

Form of application may be obtained from the Director of Education, 13, High Street, Worcester, to be returned as soon as possible. E7960

LONDON COUNTY COUNCIL

WESTMINSTER TECHNICAL COLLEGE, VINCENT SQUARE, S.W.1

SENIOR LECTURER

Required 1 January, 1960, or as soon after as possible; SENIOR LECTURER in Department of Civil Engineering; must be graduate with good industrial and full-time teaching experience.

Subjects offered are those usually taken in an H.N.C. Course in Civil Engineering.

Salary scale £1550 by £50 to £1750, plus London allowance £38 or £51.

Application forms, from Secretary at College, to be returned not later than 11th December. (2596). E8051

QUEEN'S COLLEGE, DUNDEE

Applications are invited for the Edward A. Deeds Fellowship in Queen's College, Dundee, within the University of St. Andrews, for research in Engineering, Chemistry, Physics, Mathematics, or any cognate subject, from a date to be arranged. The Fellowship (open to persons of either sex) will be tenable for three years and is of value not exceeding £900 per annum; F.S.S.U.–Family Allowance benefits. University Lecturer status. Fellow may be required to do a limited amount of teaching in the Department in which he works. Ten copies of application, with names of three referees, to the undernoted within three weeks of the appearance of this advertisement.

PATRICK CUMMING,
Joint Clerk to the University Court,
Queen's College, Dundee.
November, 1959 E8033

PUBLIC APPOINTMENTS

UNIVERSITY OF SYDNEY

LECTURESHIP/SENIOR LECTURESHIP IN MECHANICAL ENGINEERING

Applications are invited for the above position.

The salary for a SENIOR LECTURER is within the range £A2200 by £A80 to £A2600 per annum; for a LECTURER within the range £A1500 by £A90 to £A2100 per annum. In each case cost of living adjustment will be allowed. The salary is subject to deductions under the State Superannuation Act. The commencing salary will be fixed according to the qualifications and experience of the successful applicant.

Under the Staff Members' Housing Scheme in cases approved by the University and its Bankers, married men may be assisted by loans to purchase a house.

Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36, Gordon Square, London, W.C.1.

Applications close, in Australia and London, on 2nd February, 1960. E8044

UNIVERSITY OF SOUTHAMPTON

RESEARCH IN STRUCTURAL FATIGUE

Applications are invited for the post of RESEARCH ASSISTANT in the Department of Aeronautics and Astronautics to undertake work on the theory of Cumulative Damage in Fatigue. Candidates should have a good mathematical background (including statistical analysis) and preferably some knowledge of the field of Metal Fatigue. Salary according to qualifications and experience up to a maximum of £800 per annum. Applications (two copies) containing the names of two referees should be sent to the Secretary and Registrar. E8039

CITY OF COVENTRY WATER UNDERTAKING

ENGINEERING ASSISTANTS

ENGINEERING ASSISTANTS (2). Applicants must have either passed Parts I and 2 of the Institution of Civil Engineers Examination, or hold a University Degree or an equivalent qualification, and must have been trained as Civil Engineers. Salary: According to qualifications—Special Grade (£785–£1070 per annum) or A.P.T. 2 (£765–£880 per annum), plus £26 per annum in certain circumstances.

The Corporation may provide assistance in respect of dwelling accommodation and removal expenses loan in appropriate cases.

The Engineering Section of the Undertaking is at present engaged on works which comprise some 30 miles of 27in.–30in. diameter pipelines, extensions to the River Severn Treatment Works to meet increase of abstraction from 9 to 13 m.g.p.d.; Central Depot reconstruction including large Workshop Block, and reconstruction of existing pumping stations.

Closing date for application, 7th December, 1959. Conditions and further particulars from the Water Engineer and Manager, Waveley Road, Coventry. E8069

AIR MINISTRY

MEDMENHAM, ROYAL AIR FORCE, BUCKS AND WATTON, NORFOLK

CIVILIAN DRAUGHTSMEN (ENGINEERING)

Air Ministry require CIVILIAN DRAUGHTSMEN (ENGINEERING) at Royal Air Force, Medmenham, Bucks and Watton, Norfolk. Candidates must be British subjects. Duties require sound knowledge of electronics. Qualifications: O.N.C. or equivalent, satisfactory completion of normal apprenticeship or equivalent training of not less than three years and workshop experience. Salary (Provincial) £530 to £736 on entry depending on age and experience rising to maximum of £850. Five-day week and 3 weeks' 3 days' annual leave. Travelling expenses in United Kingdom in excess of 7s. 6d. will be paid to all candidates callee for interview. For application forms and full particulars, apply to Air Ministry, C.E.4b, Princes House, Kingsway, London, W.C.2, or any Employment Exchange quoting Order No. City 3308. E8027

PUBLIC APPOINTMENTS

GLANTAWE HOSPITAL MANAGEMENT COMMITTEE

MORRISTON HOSPITAL
(501 BEDS)
SWANSEA

SENIOR ENGINEER

Applications are invited for the appointment of SENIOR ENGINEER at the above hospital. Candidates must have served an apprenticeship in mechanical engineering and possess a sound knowledge of the principles and practices of the efficient operation of steam boiler plant and engineering services generally.

Possession of one of the following qualifications is essential:

1st Class Certificate of Competency in Marine Engineering or equivalent Naval certificate.

City and Guilds Full Technological Certificate in Plant Engineering (1st Class) (from 1947) or approved equivalent qualification.

Conditions of service and salary will be as laid down by the Whitley Council, i.e., £680 p.a. by £25 (3) by £30 (2) to £815 p.a. (Salary scale at present under review.)

The appointment is subject to one month's notice on either side.

Forms of application are obtainable from the undersigned at Glantawe H.M.C., St. Helen's Road, Swansea, to whom they should be returned not later than 9th December, 1959.

T. E. JONES,
Group Secretary.
E8047

GOVERNMENT OF THE FEDERATION OF RHODESIA AND NYASALAND

MINISTRY OF WORKS

VACANCY: ASSISTANT STRUCTURAL ENGINEER

Applicants must be Corporate Members of the Institution of Civil and/or Structural Engineers, or hold a Degree in Engineering with a minimum in the latter instance, of four years' post-qualification experience.

Applicants must have a sound knowledge of reinforced concrete design and detailing; some experience of steel structure is desirable.

Duties in the main consist of preparing design and details of reinforced concrete frames for Government buildings.

The commencing salary for a person holding one of the above qualifications and having four years' relevant experience, will be £1300 per annum, rising by yearly increments of £50 to £1650 per annum.

Application forms and further details from the Secretary (R), Rhodesia House, 429, Strand, London, W.C.2. Closing date 15th December. E8073

REPUBLIC OF THE SUDAN

ENGINEER

Applications are invited from those suitably qualified to fill a vacancy of ENGINEER—Ginning Factories with the Sudan Gezira Board.

Applicants must have served a recognised apprenticeship or a course of training in engineering and have had several years' experience in the maintenance of electric motor-driven textile plant, hydraulic equipment, fans, &c. A knowledge of maintenance and operation of 250/300 b.h.p. Diesel Engines is desirable. Possession of H.N.C. or equivalent would be an advantage.

Appointment will be on contract for a period of three years in the salary range £S.1000 to £S.1500. A gratuity representing one-fifth of total basic salary received will be paid on the satisfactory completion of the contract. A cost of living allowance is payable and an initial outfit grant of £S.60 is paid on appointment. Free accommodation with electricity and water is provided by the Board. Annual leave is 60 days. There is no income tax payable in the Sudan at present.

Applications in writing, giving fullest details of qualifications and experience and age with copies of two recent testimonials to Personnel Section, Sudan Embassy, Cleveland Row, St. James's, London, S.W.1. Closing date, 14th December, 1959. Quote reference L.E.7-4/2420. E8008

Classified Advts. continued on page 162

PUBLIC APPOINTMENTS

NORTH EAST METROPOLITAN REGIONAL HOSPITAL BOARD

EXPANSION OF ENGINEERS' DEPARTMENT

The Board is engaged in an expanding programme of hospital development, and the undermentioned appointments offer to Engineers particularly valuable experience in planning and supervising the installation of large-scale heating and hot-water systems, conversion of boilers to oil-firing, ventilation of operating theatres, engineering services and equipment for laundries and kitchens.

Own car may be used for visiting hospitals, &c., for which adequate mileage allowance paid. Posts pensionable and excellent prospects of promotion. Previous hospital experience is NOT essential. ALL SALARY SCALES NOW BEING REVIEWED.

ASSISTANT ENGINEERS (Mechanical/Heating and Ventilating)

Salary according to age and experience up to a maximum of £1105. Applicants must be Graduate Members of the Institution of Heating and Ventilating Engineers and have passed the associate membership examination or hold exempting qualifications. The posts offer opportunities to cover the whole field of heating, ventilating, and mechanical engineering in hospitals.

ENGINEERING ASSISTANTS, GRADE I

Salary £700 (at age 23), to £1055. Applicants must hold the Higher National Diploma or Certificate in Mechanical Engineering, a recognised engineering degree, or their equivalent.

Application forms from Secretary, North East Metropolitan Hospital Board, 40, Eastbourne Terrace, W.2. E8057

BRITISH TRANSPORT DOCKS

CHIEF DOCKS ENGINEER'S DEPARTMENT, HULL DOCKS

ASSISTANT ENGINEER (MECHANICAL)

British Transport Docks invite applications for the position of ASSISTANT ENGINEER (MECHANICAL) in the Chief Docks Engineer's Department, Hull Docks.

Applicants should preferably have had experience in docks mechanical engineering, including all types of appliances and machinery. Corporate Membership of the Institution of Mechanical Engineers desirable. Salary range £1150–£1315 per annum. Contributory superannuation scheme and certain rail travel facilities.

Applications, giving age, experience and present position, should be forwarded to : Staff and Establishment Officer, British Transport Docks, 163, Euston Road, London, N.W.1, to arrive not later than Friday, 4th December, 1959. E8016

BOROUGH OF FALMOUTH

ARGAL DAM

SENIOR CIVIL ENGINEER

Applications are invited for the appointment of a SENIOR CIVIL ENGINEER, to work initially in London on the final design and contract documents for raising a Concrete Dam by stressed cable methods and subsequently, if so required, as Resident Engineer.

Applicants should preferably be qualified Civil Engineers with experience in concrete dam construction and in the design and construction of stressed concrete structures.

Salary will be determined in accordance with qualifications and experience.

Applications, with full details and the names of two persons to whom reference can be made, should be sent to Messrs. Rofe and Raffety, 9, Brewer's Green, Buckingham Gate, London, S.W.1, not later than Friday, 4th December, 1959. E7990

MINISTRY OF AVIATION

PHYSICISTS, CHEMISTS, ENGINEERS, MATHEMATICIANS

PHYSICISTS, CHEMISTS, ENGINEERS, MATHEMATICIANS required in Research and Development Establishments of Ministry of Aviation, mainly in Southern England, offering wide range of problems. Appointments in grades of (a) SENIOR SCIENTIFIC OFFICER (£1166–£1380) ; (b) SCIENTIFIC OFFICER (£615–£1090). Starting salary according to experience. Superannuation under F.S.S.U. 1st or 2nd class Honours Degree or equivalent required and for (a) at least 3 years' post-graduate research experience. GOOD PROMOTION PROSPECTS. Forms from M.L.N.S., Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting A.438/9A/BF. E8028

MARSTON GREEN MATERNITY HOSPITAL

BERWICKS LANE, MARSTON GREEN, NEAR BIRMINGHAM

ASSISTANT ENGINEER

ASSISTANT ENGINEER required. Applicants must have completed an Apprenticeship in mechanical engineering and have sound knowledge of the principles and practices of hospital boiler plant engineering and electrical services generally. Preference will be given to a candidate who has studied for the ordinary National Certificate or its equivalent. Salary : £545 rising to £670 per annum. Post permanent and superannuable. Detailed applications with full information relating to training and service and naming 3 referees to Hospital Secretary within 21 days. E8015

PUBLIC APPOINTMENTS

CITY OF BRADFORD

ENGINEERING ASSISTANTS

Applications are invited for the following superannuable appointments in the City Engineer and Surveyor's Department, on the grades indicated.

(a) SENIOR ENGINEERING ASSISTANT (HIGHWAYS), Post 216, Grade A.P.T. V (£1220–£1375).
(b) SENIOR ENGINEERING ASSISTANT (STRUCTURAL), Post 218, Grade A.P.T. V (£1220–£1375).
(c) SENIOR ENGINEERING ASSISTANT, Post 13, Special Grade (£785–£1070).
(d) ENGINEERING ASSISTANT, Post 120, Grade A.P.T. I or Special (£610–£765 or £785–£1070).
(e) JUNIOR ENGINEERING ASSISTANTS, Posts 52 and 63, Grade A.P.T. I (£610–£765).

Applicants for Posts (a), (b) and (c) should preferably hold an Engineering Degree, be A.M.I.C.E./A.M.I.Mun.E., and have had for post (a) good general experience in Municipal Engineering with special experience in construction and improvements of Highways ; for post (b) have had special experience in design of reinforced concrete and steel structures and multi-storey flat construction ; and for post (c) have had a good general civil engineering training.

Applicants for (d) should have completed their professional training. Salary on Special Grade will be payable to the successful candidate holding an Engineering Degree or be A.M.I.C.E./A.M.I. Mun.E.

Applicants for (e) should have completed their professional training and have had experience in Municipal and/or Civil Engineering.

Applicants should have completed their National Service. No housing accommodation can be provided by the Corporation.

Applications, on forms to be obtained from the City Engineer and Surveyor, Town Hall, Bradford, 1, together with three testimonials, must be received by the undersigned by 19th December, 1959.

W. H. LEATHEM,
Town Clerk.

Town Hall,
Bradford, 1. E8062

MINISTRY OF AVIATION

LONDON

TECHNICIAN

Ministry of Aviation requires a TECHNICIAN, based in London, for inspection of machine tools and workshop plant against inventory records and their practical assessment to meet current and anticipated demands. Technical investigation of breakdowns and complaints at contractors' works, writing technical reports and the preparation of specifications.

Qualifications : Recognised engineering apprenticeship ; O.N.C., C. & G. Finals or equivalent. Sound practical knowledge modern machine tools (British and Foreign) and plant. Production experience in aircraft industry an advantage. Salary : £900 (age 30)–£1065 p.a.

Application forms from Manager (P.E.2643), M.O.L., Professional and Executive Register, Atlantic House, Farringdon Street, London, E.C.4. E8034

ROAD RESEARCH LABORATORY

HARMONDSWORTH, MIDDLESEX

CIVIL ENGINEERS, MATERIALS (RESEARCH) ENGINEERS

Road Research Laboratory (D.S.I.R.), Harmondsworth, Middlesex, requires CIVIL ENGINEERS, MATERIALS (RESEARCH) ENGINEERS, in Senior Scientific/Scientific Officer grades, to be based on Tropical Section of R.R.L. and available for secondment to overseas territories to study locally available road-making materials, and help in developing methods of road-making appropriate to local conditions. Preference given to engineers with some field experience. After a period of laboratory training they will be posted for tours in British overseas territories, returning to work in the Tropical Section of the Road Research Laboratory between tours.

Qualifications : 1st or 2nd Class Hons. Degree. At least three years' post-graduate experience for S.S.O. grades. Starting salaries within the range : S.O., £655–£1150 ; S.S.O., £1233–£1460. Normal prospects of promotion to Principal Scientific Officer in mid-thirties (range up to £2120), with possibilities of higher posts. Five-day week.

Forms from Ministry of Labour, Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting E.347/9A. Closing date 15th January, 1960. E8067

SWINDON CORPORATION WATER UNDERTAKING

APPOINTMENT OF PRINCIPAL CIVIL ENGINEERING ASSISTANT

A.P.T. GRADE "V" (£1220–£1375)

Applications are invited for the above new appointment in the WATER SECTION of the Borough Surveyor and Water Engineer's Department.

The person appointed will be directly responsible to the Deputy Water Engineer for the civil engineering development work in this rapidly expanding Water Undertaking. Applicants should have had considerable experience in underground water supply, service reservoirs and trunk mainlaying work, and should be Corporate Members of the Institution of Civil Engineers and of the Institution of Water Engineers.

Applications on forms to be obtained from the Town Clerk, Civic Offices, Swindon, must be returned not later than 31st December, 1959. E8046

PUBLIC APPOINTMENTS

ROYAL NAVAL SCIENTIFIC SERVICE

SENIOR SCIENTIFIC OFFICERS AND SCIENTIFIC OFFICERS

SENIOR SCIENTIFIC OFFICERS and SCIENTIFIC OFFICERS required in following localities :

LONDON AREA : MECHANICAL ENGINEER with sound knowledge of basic principles of thermo and fluid dynamics, to carry out research programme in particular field of applied hydrodynamics. Experience in modern methods of design and research on axial flow compressors, turbines or pumps an advantage. MECHANICAL ENGINEER for research on precision gear design. MECHANICAL ENGINEER for work on propulsion problems. APPLIED MATHEMATICIAN for research of basic nature on stability of underwater vehicles ; knowledge of theoretical hydrodynamics and theory of control mechanisms an advantage. APPLIED MATHEMATICIAN or THEORETICAL PHYSICIST for acoustic analysis. APPLIED MATHEMATICIAN for work with electronic computers, with special reference to research into general underwater physical problems. ELECTRONIC PHYSICISTS for data handling and analysis problems. EXPERIMENTAL PHYSICIST for research in underwater acoustics. PHYSICIST interested in operation performance. CLASSICAL PHYSICISTS.

BALDOCK : PHYSICISTS or APPLIED MATHEMATICIANS for research in Metal or Quantum Physics.

PORTSMOUTH : PHYSICISTS with experience in field of microwave techniques. ELECTRONIC/ELECTRO-MECHANICAL ENGINEERS (experience in servo-mechanisms an advantage).

HASLEMERE : ELECTRONIC ENGINEER.

PORTLAND : PHYSICISTS or APPLIED MATHEMATICIANS for research in underwater acoustics. PHYSICISTS (general). ELECTRICAL ENGINEERS with advanced electronic design experience. MECHANICAL ENGINEERS. PHYSICAL CHEMISTS.

POOLE : CHEMICAL ENGINEERS. CHEMISTS with experience in rubber technology.

ROSYTH : MECHANICAL ENGINEER with experience in welding development. ELECTRONIC PHYSICISTS.

Candidates must normally be natural born British subjects of natural born British parents, with First or Second-Class Hons. Degrees or equivalent qualifications. S.S.O.s must have had three years' post-graduate experience and be not less than 26 years of age. Salaries (men) : S.S.O., £1233–£1460 ; S.O., £655–£1150 (London), somewhat lower in provinces.

Appointments unestablished (with F.S.S.U. benefits), but opportunities may occur for those under 32 to compete for established posts.

Forms from M.L.N.S., Technical and Scientific Register (K), 26, King Street, London, S.W.1 (quote A.483/9A). E7844

SURREY COUNTY COUNCIL

APPOINTMENTS

Applications invited for the following appointments :

SPECIAL GRADE. (£785–£1070 p.a., plus £30 p.a. London Allowance).

This grade is particularly suitable for newly qualified Assistants.

HEATING AND VENTILATING ENGINEERS. Must be A.M.I.H.V.E. and experienced in heating and ventilating installations.

GRADE I (£610–£765 p.a.) and GRADE II (£765–£880 p.a.), plus up to £30 p.a. London Allowance according to age.

HEATING ENGINEERING ASSISTANT. Must hold H.N.C. or be Grad. I.H.V.E., and be experienced in layout and design of heating and h.w. services in buildings.

Candidates will be appointed at the appropriate point within the scale according to age and ability.

Full details, present salary and three copy testimonials to County Architect, County Hall, Kingston, as soon as possible. E7975

TRENT RIVER BOARD

APPOINTMENT OF ASSISTANT ENGINEER I.

Applications are invited from suitably qualified engineers for the appointment of an ASSISTANT ENGINEER I at the Board's Head Office at Nottingham. Salary within A.P.T. Grades III-IV (£880–£1220) of the National Scheme of Conditions of Service, according to qualifications and experience. The appointment will be subject to the Local Government Superannuation Acts.

The successful applicant will be engaged mainly on the design of major river improvement works and preference will be given to candidates with previous experience of land drainage.

Applications, with full particulars, including copies of testimonials or names of at least two referees, must reach Marshall Nixon, M.B.E., T.D., M.I.C.E., the Engineer to the Board, 206, Derby Road, Nottingham, not later than 11th December, 1959.

IAN DRUMMOND,
Clerk of the Board.

E7959

MIDDLESEX HOSPITAL, LONDON, W.1

SENIOR ENGINEER

Vacancy for SENIOR ENGINEER. Salary scale £770 by £25 (1) by £30 (4) to £915, plus £30 London weighting. Candidates, age 30 to 40 must have served apprenticeship in mechanical engineering or otherwise acquired practical mechanical and electrical engineering experience. Also sound knowledge of principles and practice of operation of boiler plants. One of the following qualifications essential : Higher National Diploma in Mechanical Engineering. Higher National Certificate in Mechanical Engineering. 1st Class Certificate of Competency in Marine Engineering or equivalent Naval Certificate. Good prospects for suitable candidate. Applications in writing to Secretary-Superintendent, by 9th December, 1959. E8053

PUBLIC APPOINTMENTS

GUILDFORD, GODALMING AND DISTRICT WATER BOARD

APPOINTMENT OF SENIOR ENGINEERING ASSISTANT

Applications are invited for the appointment of SENIOR ENGINEERING ASSISTANT at a salary in accordance with Grade A.P.T. II (£765–£880 per annum).

Candidates should have had good experience in the general engineering work of a Water Undertaking, and have passed part of the Associate Membership Examination of the Institution of Civil Engineers.

The appointment will be subject to the National Scheme of Conditions of Service, the Local Government Superannuation Acts, and to the passing of a medical examination.

Applications, stating age, training, present and previous appointments and experience, and names and addresses of two referees, must be received by the Chief Engineer, "Branksome," Filmer Grove, Nightingale Road, Godalming, not later than Monday, the 14th December, 1959.

Housing accommodation will be available for a married man.

H. C. WELLER,
Clerk to the Board.

Municipal Offices,
High Street,
Guildford. E8023

CITY OF BIRMINGHAM WATER DEPARTMENT

ASSISTANT ENGINEERS

Applications invited from Chartered Civil Engineers for above appointments. Salary within (*a*) Grade A.P.T. IV, £1065–£1220 per annum (considerable water engineering experience essential), and (*b*) Special Grade for Engineering Assistants, £785–£1070 per annum (water engineering experience desirable). The Engineer appointed to (*a*) would be engaged upon development of new source of supply and (*b*) on new water supply works in or near Birmingham. Appointments permanent and pensionable—medical examination. Canvassing disqualifies.—Application forms from General Manager, Water Department, Council House, Birmingham, 3, returnable by 7th December, 1959.

E8022

EDUCATIONAL

A.M.I.MECH.E., B.Sc., City and Guilds, &c. Guarantee Postal Courses for all Exams. and Technical Divisions from Elementary to Degree standard including Automation Techniques. Approximately 95 per cent. successes. 148-page prospectus free, on request.—B.I.E.T. (Dept. 22), 29, Wright's Lane London, W.8. E114

TENDERS

DUNMOW RURAL DISTRICT COUNCIL

HATFIELD HEATH AND HATFIELD BROAD OAK SEWERAGE AND SEWAGE DISPOSAL

CONTRACT NO. 16

TENDERS are invited on a fixed price basis in accordance with the Ministry of Housing and Local Government Circular No. 31/57 for the CONSTRUCTION OF SEWERAGE AND SEWAGE DISPOSAL WORKS at Hatfield Heath and Hatfield Broad Oak.

The sewerage in Hatfield Heath and Hatfield Broad Oak, comprises in all the laying of about 1310 linear yards of 9in. diameter S.G.W. sewer, 780 linear yards of 6in diameter S.G.W. sewer, 830 linear yards of 6in. diameter spun iron rising main, 4in. and 6in. diameter S.G.W. house connections, construction of 7 brick and 12 precast concrete manholes, together with a sewage pumping station in reinforced concrete.

Extensions are to be made to the existing sewage disposal works at Hatfield Heath and comprise the construction of sand filters in reinforced concrete, together with ancillary pipework.

General Conditions of Contract, Specification, Bills of Quantities and Drawings may be obtained from the Council's Consulting Engineers, Messrs. J. D. and D. M. Watson, MM.I.C.E., 67, Tufton Street, Westminster, S.W.1, on and after 7th December, 1959, on payment of a deposit of ten guineas, refundable only to Contractors who submit bona fide tenders and return all documents and drawings. Deposit cheques should be made payable to Dunmow Rural District Council.

The Council do not bind themselves to accept the lowest or any tender.

Tenders must be returned in envelopes which do not bear any name or mark indicating the sender, endorsed "Tender for Sewerage Contract 16," and delivered at the office of the undersigned by noon on 15th January, 1960.

A. H. BURTON,
Clerk of the Council.

Council Offices,
Dunmow, Essex. E8045

TENDERS

INDIA STORE DEPARTMENT

TRIMMING PRESS FOR LIGHT ALLOY FORGINGS

The Director General, India Store Department, Government Building, Bromyard Avenue, Acton, London, W.3, invites TENDERS for the supply of :

REF. No. 20074/59/NEN/HAL

	Quantity
TRIMMING PRESS FOR LIGHT ALLOY FORGINGS, 300 tons, Single Action, Double Crank, Straight Side.	1 off

The Tender forms with Schedules and Specifications which are returnable on 28th December, 1959, may be obtained from the above Office (C.D.N. Branch) on payment of a fee of 10s. (not refundable) for each tender.

The applications for Tenders should clearly state the above reference number. E8002

SITUATIONS VACANT

APPLICANTS ARE ADVISED TO SEND COPIES NOT ORIGINALS OF THEIR TESTIMONIALS UNLESS OTHERWISE REQUESTED.

APPLICATIONS ARE INVITED from ambitious and resourceful men to fill the position of TECHNICAL ASSISTANT to the Sales Manager of Electric Lamp Machinery Manufacturers near London. A permanent, progressive and interesting job is offered to the right person, who must possess a sound engineering and commercial background in the trade.—Applications, with full particulars of education, experience and salary required to BOX No. E171, "The Engineer." A

AUTOMOTIVE DEVELOPMENT ENGINEER.—A young and active company with an expanding Research and Development Department wishes to engage a qualified Development Engineer. This appointment calls for a man of 25 to 30 years of age who has attained Higher National Certificate (Mechanical) and has sound practical experience on development work, preferably in the chassis component field. Applications should contain full details of experience, education and technical qualifications and current salary.—BOX No. E2639, "The Engineer." A

BOOKS and PUBLICATIONS

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SITUATIONS VACANT

BRITISH ENKA LIMITED

MECHANICAL ENGINEER for large, progressive Producers of Man-Made Fibres. Successful applicant will join team of Engineers engaged on maintenance and capital projects. Minimum qualifications H.N.C. Mechanical or Chemical Engineering, preferably Corporate Member appropriate Institution, with supervisory experience. Post is permanent and progressive, with good salary. Pension scheme.—Applications, in confidence, stating age, qualifications and experience, addressed to Personnel Manager, British Enka, Ltd., Aintree, Liverpool. E8049 A

CADBURY BROTHERS LTD.

have a vacancy for

MACHINE DESIGNER

With experience in the design of special-purpose machinery. Applicants should preferably have gained the Higher National Certificate in Engineering or have similar qualifications. Some experience in the Food Industry would be an advantage. Housing accommodation available. —Applications, stating age, experience, qualifications and salary, should be addressed to Chief Engineer, Cadbury Bros., Ltd., Bournville, Birmingham. E8050 A

DESIGN DRAUGHTSMEN FOR SOUTH AFRICA

A leading heavy engineering works in SOUTH AFRICA requires DESIGN DRAUGHTSMEN with mechanical engineers diploma, Higher National Certificate or equivalent. Sound theoretical knowledge of mechanical engineering, design methods and at least five years' practical experience in medium/heavy engineering essential.

Housing available. Pension and medical benefit funds.

Salary in accordance with qualifications and experience. Facilities exist for advancing travelling expenses to South Africa on contract basis.

Applications, stating age, qualifications, present salary, previous experience, and marital status, must be addressed to BOX 729, c/o Walter, Skinner, Ltd., 20, Copthall Avenue, London, E.C.2. E8031 A

DESIGNER-DRAUGHTSMAN required, preferably with H.N.C. in Mechanical Engineering. Non-contributory pension scheme available.—Applications to Metalectric Furnaces, Ltd., Cornwall Road, Smethwick, 40, Staffs. E2638 A

DESIGNER-DRAUGHTSMAN for interesting project. Congenial surroundings. Peckham district. Experience of small pressed and die cast mechanisms required. H.N.C. or similar an advantage.—B. J. Veneear, Ofrex, Ltd., Ofrex House, Stephen Street, W.1 (MUS.3686). E2641 A

DIESEL DEVELOPMENT ENGINEER, aged 25 to 30 years, is required by an expanding organisation in the automotive field. Qualifications for this appointment are minimum Higher National Certificate and experience in the combustion problems of high-speed diesel engines. Details in application for this appointment should include previous experience, educational and technical background and an indication of current salary.—BOX No. E2640, "The Engineer." A

ELECTRONICS/ELECTRICAL DEVELOPMENT ENGINEER required to join small Mechanical Engineering Group engaged on variety of interesting projects, including Aeronautics.—BOX No. E2642, "The Engineer." A

HAWKER SIDDELEY INDUSTRIAL DIVISION
BRUSH ELECTRICAL ENGINEERING CO., LTD., LOUGHBOROUGH

GENERAL ENGINEERING DIVISION

YOU CAN PROGRESS AS WE EXPAND

If you have technical knowledge (corporate membership of a Senior Institution, H.N.C. or O.N.C.), some experience of electric power generation, distribution or utilisation of electrical energy and are looking for employment where initiative is welcomed, then you will be interested in joining our expanding General Engineering Division.

There are vacancies for ENGINEERS, DRAUGHTSMEN and ESTIMATING AND CONTRACT ENGINEERS to handle a wide range of comprehensive projects involving steam, gas expansion and gas combustion turbines, diesel engines, up to the largest sizes, transformers, switchgear, rotating machines and associated equipment.

Applications, WHICH WILL BE TREATED IN THE STRICTEST CONFIDENCE, should give brief details of experience and qualifications, and should be addressed to the :

Chief Personnel Officer,
Brush Electrical Engineering Company Limited,
Loughborough, Leics.

and should quote reference PL 9013.

E7999 A

EXPANDING COMPANY, Manchester area, requires : (1) TECHNICAL ENGINEER, good Degree, preferably with some years' drawing-office experience ; (2) EXPERIENCED DESIGN DRAUGHTSMEN. Varied work, including medium heavy automatic equipment. State qualifications, experience and salary.—BOX No. E2635, "The Engineer." A

SITUATIONS VACANT

ENGINEERS with Graduate or equivalent qualifications required, with some experience as follows: (a) Project Engineers having design experience of rolling mills, strip processing lines, hydraulic forging and extrusion presses and related mechanical and electrical equipment ; (b) Construction Engineers having experience of planning, layout and installation of similar equipment. The positions represent good opportunities for men having five to eight years' experience with plant suppliers to generalise and consolidate their experience in the organisation of a user of such plant. Opportunities are available both in the London Head Office and at the company's South Wales plant.—Reply, giving full details of education and experience, to Personnel Officer, Northern Aluminium Co., Ltd., Bush House, Aldwych, London, W.C.2. E8064 A

HUDSWELL, CLARKE AND CO. LTD.
MECHANICAL HANDLING DIVISION

Applications are invited from men over 27 years of age with H.N.C. Mechanical, for the position of DESIGN ENGINEER in the Mechanical Handling Division. The successful applicant would be responsible for the preparation of schemes incorporating Materials and Mine Car Handling Equipment for Colliery reconstructions, together with the control of Production Design.

The salary will depend upon qualifications and experience, and applications, giving full details of age, qualifications and past experience, should be addressed to : The Senior Engineer, Mechanical Handling Division, Jack Lane, Leeds, 10. E8019 A

LEADING PETROLEUM COMPANY have vacancies in London and the South of England for qualified Engineers. Candidates should have had thorough training in workshops and possess either Corporate Membership of the Institutions of Civil or Mechanical Engineers or have passed Parts "A" and "B" of one of these Institutions' examinations or have qualifications entitling them to exemption from such examinations. Experience on pumps and pipelines or building construction would be advantageous. Excellent conditions of employment and starting salary appropriate to qualifications and experience.—Apply, giving full details of age, qualifications and experience to BOX No. E7887, "The Engineer." Replies can only be sent to those selected for interview. A

MAJOR INDUSTRIAL COMPANY with Works in many parts of the country require a

QUALIFIED ENGINEER

to undertake technical investigation work.

The work is in connection with the investigation of the performance of the Company's products at the Company's Works and customers' Works.

A Graduate Engineer in Mechanical Engineering would be preferred but it is necessary for applicants to have had a good engineering background. The successful candidate will be located at Head Office in London. Age up to 30 years.

Write, stating details of age, qualifications and experience to BOX No. E8011, "The Engineer."

A

MECHANICAL DESIGNER-DRAUGHTSMEN required, capable of taking responsibility for original design and development in connection with Mechanical Handling Plant for Nuclear Fuel, Bulk Materials and Wagon Marshalling. Profit-sharing and superannuation schemes and canteen facilities.—Write, giving full particulars of qualifications, experience and salary expected, to : Strachan and Henshaw, Ltd., St. Philips, Bristol, 2, marking your envelope "F.J.B." E7958 A

MUNICIPAL MUTUAL INSURANCE LIMITED has a vacancy for a MECHANICAL ENGINEER SURVEYOR in London. Technical qualification : First Class Ministry of Transport certificate. ALSO in London a SURVEYOR competent to examine cranes and lifting tackle. Technical qualifications : Ministry of Transport or Higher National certificate. Posts are pensionable and permanent to satisfactory candidates who should have served an apprenticeship and have sound practical and theoretical knowledge. Salary : £800 rising to £1100 per annum.—Apply in own handwriting, marking the envelope "Application Engineer Surveyor," and "Private and Confidential" to the Chief Engineer, 22, Old Queen Street, Westminster, S.W.1. E8013 A

PORT OF MANCHESTER
ENGINEERING APPOINTMENT

Applications are invited for a Senior position on the staff of the Chief Engineer.

The position is one which offers excellent prospects of promotion and will carry a salary commensurate with the responsibilities entailed.

Candidates, who must be Corporate Members of the Institution of Civil Engineers, should not only have extensive experience in dock and harbour construction and maintenance but should also have first-class executive and administrative experience.

The successful candidate will be required to pass a medical examination and to become a member of the Company's Contributory Superannuation Scheme.

Applications, stating age, qualifications and full details of experience, should be addressed to the Chief Engineer (marked "Personal"), The Manchester Ship Canal Company, Ship Canal House, King Street, Manchester, 2, not later than the 15th January, 1960.

E8041 A

Classified Advts. continued on page 164

SITUATIONS VACANT

MONSANTO CHEMICALS LIMITED
TECHNICAL ASSISTANTS—
ENGINEERING DEPARTMENT
FAWLEY WORKS

Applications are invited from men aged 25–30 years, of H.N.C. educational level, for two posts at our Fawley Works near Southampton. Duties in both cases will include labour and material estimating, scheduling and cost control. The posts are staff appointments to the Engineer concerned ; direct supervision of labour is not involved.

1. H.N.C. Mechanical/Production, or equivalent, required. Experience in estimating from drawings and a knowledge of medium-range engineering work are essential. Knowledge of oil-fired boilers an advantage.
2. H.N.C. Elect. (Distribution and Utilisation), or equivalent, required. Knowledge of control and relay circuits and industrial distribution systems and equipment up to 11kV is essential. A knowledge of maintenance systems and process instrumentation is desirable.

Please send written applications giving details of age, qualifications, experience and quoting reference (1) or (2) to DL.113, Personnel Department, Monsanto Chemicals, Limited, Monsanto House, 10/18, Victoria Street, London, S.W.1.

E8007 A

PUMP ENGINEER required for work on the application and specification of Centrifugal Pumps. It is envisaged that suitable applicants will be not less than 30 years of age and have had a minimum of ten years' experience in connection with the manufacture of all types of Centrifugal pumps. They will probably be at present engaged as a Section Leader in the Drawing Office of a reputable firm of pump manufacturers, or in some similar capacity. Give full details regarding age, experience, present position, technical qualifications, and salary required.—BOX No. E8014, "The Engineer." A

SECURITY EQUIPMENT MANUFACTURERS (London) require TECHNICAL ASSISTANT for Director. Engineering, structural and some sales experience necessary. Send full details, career, salary, &c.—BOX No. E8055, "The Engineer." A

SENIOR DESIGN DRAUGHTSMEN, familiar with small mechanisms, &c., required by progressive and expanding Company situated approximately 20 minutes from Waterloo. The positions offered are permanent and provide excellent prospects for versatile men who seek interesting work in a new field.—BOX No. E169, "The Engineer." A

SENIOR DRAUGHTSMAN—age 28–35—required for interesting and varied work on the design and layout of Plant for the manufacture of Chemicals. Must be experienced in the design of pressure vessels and pipework. A non-contributory superannuation scheme is in operation.—Applications, stating particulars of experience and technical qualifications, should be addressed to : The Works Engineer, Midland Silicones, Ltd., Barry, Glamorgan. E7995 A

SENIOR PROJECTS ENGINEER required for layout, design and specification of plant. Must have extensive experience of mechanical handling, vessels and pipework, brewery plant or bottling machinery. Also INTERMEDIATE DESIGN DRAUGHTSMAN required, at least 2 years' D.O. experience (mechanical) ; practical training and O.N.C. preferred. Salaries commensurate with experience, qualifications and responsibilities. Canteen. Pension scheme.—Apply in writing with full particulars, Chief Designer, G. HOPKINS AND SONS, LIMITED, United House, North Road, London, N.7. E8040 A

SENIOR RATEFIXER / METHODS ENGINEER required for Fabrication work. Experience of machine shop practice and electrical work would be an advantage. Salary according to experience.—Replies, in confidence, to Works Manager, H. and E. Lintott, Ltd., Foundry Lane, Horsham, Sussex. E7997 A

SIR ALEXANDER GIBB AND PARTNERS, Consulting Engineers, Queen Anne's Lodge, Westminster, London, have vacancies in their Electrical and Mechanical Dept. for : (a) ELECTRICAL ENGINEERING DRAUGHTSMAN with practical experience in electrical distribution, power and lighting ; (b) MECHANICAL ENGINEERING DRAUGHTSMAN with practical experience in general services installations, steam gas and compressed air, &c. In both cases practical experience and ability essential to design complete schemes, including drawings and tender specifications. Salaries necessarily will be based on experience and applications should indicate age, technical education and practical experience, with past employers. E8061 A

STEAM POWER STATION
SUPERINTENDENT
IN CANADA

The above vacancy occurs at a 30MW station. Candidates should be well educated and qualified and capable of taking complete charge of operation and maintenance. They must have had several years' practical generating station experience. Present steam conditions are 400 p.s.i., but knowledge of pressures to 900 p.s.i. would be useful for future development. Salary 7500 Canadian dollars per annum. Applications should give full details of age, education, qualifications and experience to :

Messrs. Mackness & Shipley,
Parliament Mansions, Abbey Orchard Street,
London, S.W.1,
quoting reference 2463.

E7968 A

STEEL TUBES.—WORKS MANAGER required. Must have wide experience in practical and executive appointments, held similar positions and be a first-class administrator. Substantial salary will be paid to man with necessary qualifications and future prospects are excellent.—Apply in confidence to the Managing Director, The Phoenix Steel Tube Co., Ltd., Phoenix Street, West Bromwich. F7920 A

SITUATIONS VACANT

THE VILLIERS ENGINEERING COMPANY, LIMITED, MARSTON ROAD, WOLVERHAMPTON

Applications are invited from suitably qualified engineers for positions of DESIGN DRAUGHTSMEN in connection with the development of high speed industrial diesel engines.

Appointments will be of Senior Executive level and will carry salaries commensurate with the responsibility.

All applications in writing, to the Personnel Manager, giving full details of qualifications and experience, also quoting present salary.

E8006 A

TOOLROOM FOREMAN (35–45 years) required for small toolroom of light engineering company situated in West Lothian. Applicants must be good disciplinarians and experienced in training apprentices. Superannuation scheme.—Write, giving full details of experience, education, age and salary required to Personnel Manager, BOX TF1501, A.K. Advg., 212a, Shaftesbury Avenue, London, W.C.2. E8036 A

WANTED, FIRST-CLASS SENIOR DESIGN DRAUGHTSMAN for firm of General Engineers in Bristol. Good knowledge of general engineering, with particular reference to pressure vessels and stainless steel fabrication. This will be a well-paid position for the top-class man.—BOX No. E164, "The Engineer." A

YOUNG CHEMICAL OR MECHANICAL ENGINEERING GRADUATE OR EQUIVALENT, aged 23–28, for small and progressive company specialising in the manufacture of heat exchangers for the chemical and metallurgical industries. Excellent prospects for advancement and travel. 5-day week.—Apply in writing to Metallurgical Engineers, Ltd., 5–15, Cromer Street, London, W.C.1. E8056 A

YOUNG ENGINEER (23–28), preferably H.N.C., to train on development side of small, busy, expanding firm of mechanical handling engineers selling nationally. Must also be interested in estimating and technical sales. Location, Llanelly, South Wales. Full details required, also starting salary.—BOX No. E2636, "The Engineer." A

YOUNG QUALIFIED MECHANICAL ENGINEER required, age about 25–30, to undertake practical development work covering a wide variety of production plant and special purpose machinery.

Qualifications must include H.N.C., or better, and good all round experience in production engineering.

Starting salary according to qualifications and experience. First class conditions of service, pension and life insurance schemes.

Please apply to :
Personnel Manager, Universal Grinding Wheel Co., Ltd., Stafford.

E7971 A

THE GARRARD ENGINEERING AND MANUFACTURING CO., LIMITED,

are desirous of obtaining the services of a

DESIGN ENGINEER

Applications are invited from YOUNG ENGINEERS who :

(i) have served an engineering apprenticeship.

(ii) have obtained at least Ordinary National Certificate, Engineering.

(iii) have at least two years drawing office experience on the design of Small Mechanisms.

The Company are engaged on work of a light Electro Mechanical Nature and the successful applicant will have the opportunity of following his work through from drawing board to Production Line.

The Company consider their staff conditions to be good and operate a non-contributory pension scheme. Assistance with housing can be given if required.

Applications in confidence should be addressed to :

THE CHIEF PERSONNEL OFFICER,
THE GARRARD ENGINEERING AND MANUFACTURING CO., LIMITED,
Newcastle Street,
SWINDON, WILTSHIRE.

E8024 A

SITUATIONS VACANT

DESIGNER-DRAUGHTSMAN

Reckitt & Sons Limited have a vacancy at their large TIN BOX PLANT for a DESIGNER-DRAUGHTSMAN (25-35 years of age) with experience in the design of can-making or similar machinery and layouts for high-speed production lines. Many interesting problems have to be tackled involving new plant installations. The position provides an opportunity for steady progress and a good salary will be offered to an experienced applicant.

The Company has a contributory pension scheme and offers good conditions of employment.

Applications should be addressed in writing to the Personnel Director, Reckitt & Sons Limited, Dansom Lane, Hull. E8043 A

SITUATIONS VACANT

CHIEF ENGINEERING INSPECTOR

to assume control of the Quality Control Department of a company engaged in the manufacturing and engineering of chemical plant.

Applicant must be a qualified Chemical or Mechanical Engineer with at least ten years' experience in the Quality Control and Inspection function, and have held a similar position in the engineering industry.

He will be responsible for setting company-wide standards of material quality and of inspection and test methods used to ensure this quality level.—Write Box DA.1312, c/o White's, 72, Fleet Street, London, E.C.4.

E8048 A

The Harland Engineering Co. Ltd., B.E.P. Works, Alloa, Scotland, has vacancies for two

SENIOR METHODS PLANNING ENGINEERS

one for welding and fabrication, and one for armature winding, notching and electrical core-building. Applicants must be experienced men with thorough knowledge of modern heavy/medium manufacturing techniques in their respective fields, and should preferably be qualified to H.N.C. standard. Positions are permanent and pensionable.—Write in confidence, stating full personal details, to the Works Manager, Department E, B.E.P. Works, Alloa.

E7828 A

RTB

CIVIL ENGINEERING

RICHARD THOMAS & BALDWINS LIMITED

have vacancies for

ENGINEERS: **ASSISTANT ENGINEERS:**
SENIOR DRAUGHTSMEN: **JUNIOR DRAUGHTSMEN:**

in the CIVIL ENGINEERING DIVISION of their CENTRAL ENGINEERING DEPARTMENT to be located at their SPENCER WORKS, LLANWERN, NEAR NEWPORT, MON.

The division is responsible for the civil engineering work in connection with the design, development and construction of plant projects within the Richard Thomas & Baldwins Limited Group of Companies.

Applicants must have been trained and have acquired knowledge and experience in reinforced concrete and/or structural design, preferably in connection with steelworks and rolling mill plants or alternatively comparable installations in medium or heavy industrial engineering.

Salary scales commensurate with qualifications and experience. Contributory Staff Pension and Life Assurance Schemes.

Application form can be obtained by writing to :—

General Manager—Engineering, Richard Thomas & Baldwins Limited, Central Engineering Department, "Coed Parc", 42, Park Street, Bridgend, Glam.

Envelopes to be endorsed "CIVIL ENGINEERING"

E7941 A

SITUATIONS VACANT

PROJECT ENGINEER

required by Internationally known Engineers in the Manchester Area. Suppliers of Rubber, Plastic and Hydraulic Machinery.

Applicants should have initiative and a high sense of responsibility. Holding University Degree or equivalent. He will be required to meet Customers and discuss their problems, with a view to getting out the necessary designs and drawing up of Specifications. Experience of Rubber and Plastic Machinery would be an advantage.

The post has a Non-contributory Pension and Life Assurance Scheme.

All applications will be treated in the strictest confidence.

Write in the first instance to : The Personnel Manager, Francis Shaw and Company, Limited, Corbett Street, Ashton New Road, Manchester, 11.

E8065 A

BROWN & POLSON, LTD.
PROJECT ENGINEERING

Due to a continuing expansion programme an opening is available for a Project Engineer to work on Chemical Process Plants, manufacturing Starch, Glucose, and a variety of starch derivatives. Attractive salary and employee benefits

— if you are —

1. Under 35.
2. Have had experience on design or installation of equipment for handling solids or liquid materials.
3. Hold a degree in Chemical/Mechanical Engineering.
4. Have the capacity to handle projects effectively from flow sheet to installation.

Send detailed application now to

Personnel Adviser,
Brown & Polson, Ltd.,
Trafford Park, Manchester, 17

E8068 A

SITUATIONS VACANT

ENGINEERING-DRAUGHTSMEN

(1) SENIOR ESTIMATOR

Applicants must have experience of medium/heavy engineering products and be used to handling technical correspondence. H.N.C. or equivalent would be an advantage.

(2) SENIOR DESIGN ENGINEER

with a first-class knowledge of Hydraulics, and capable of working on his own initiative on medium/heavy machinery, for the Rubber and Plastics Industry. H.N.C. or equivalent preferred.

(3) DESIGN DRAUGHTSMAN

with a sound experience in General Engineering, knowledge of Rubber and Plastic Machinery an advantage. H.N.C. or equivalent preferred.

(4) JIG & TOOL DRAUGHTSMAN

required for the Design of Jigs and Tools and Plant Layouts in a General Engineering Shop.

The vacancies are permanent and progressive with a non-contributory pension and life assurance scheme.

Apply in the first instance to : The Personnel Manager, Francis Shaw & Company Limited, Corbett Street, Ashton New Road, Manchester, 11.

E8066 A

SITUATIONS VACANT

EXPERIENCED SALES AND CONTRACTS ENGINEER

required for the Diesel Engine Department, with sound knowledge of Marine and Industrial Diesel Engineering.

SENIOR MECHANICAL DESIGNER

required, preferably with Internal Combustion Engine experience, and to H.N.C. standard.

Generous Pension Scheme and comprehensive amenities. Excellent conditions of employment.—Apply, giving full details of experience, to The Personnel Manager, W. H. Allen Sons and Co., Ltd., Bedford.

E7982 A

SITUATIONS VACANT

D. NAPIER & SON LTD.

ACTON, W.3
require

SPECIALIST PRODUCTION ENGINEERS

Outstanding opportunities exist for qualified Mechanical and Electrical Engineers to develop modern production techniques in the following fields :—

Resistance and Fusion Welding
Ultrasonic Testing
Spark Machining
Precision Fabrication

High salaries will be paid to applicants having the right experience, who can bring enthusiasm and energy to this interesting work.

If you would like to hear more about these opportunities, we should be very pleased to hear from you in confidence. Please reply to : D. Napier & Son, Dept. C.P.S., Marconi House, 336/7, Strand, London, W.C.2, quoting reference E794G.

E8035 A

OVERSEAS APPOINTMENTS LTD.

have been asked through one of their associated companies in The P.E. Group to assist in the selection of

A CHIEF ENGINEER

for an important post

IN NEW ZEALAND

The Chief Engineer is required by an expanding group of engineering companies seeking to strengthen its management and exploit its manufacturing and distributing facilities to the full.
Management is progressive, modern methods of planning and control are being installed, and labour relations are good. Headquarters are in a country town where climate, educational, medical and sporting facilities are excellent. Other companies are in Auckland and Wellington.
The man selected should be a qualified mechanical engineer between 32 and 40, with university and/or public school education and executive experience in light engineering.
Salary is commensurate with responsibility. There is a contributory superannuation scheme and generous assistance will be provided towards housing, furniture and car, with free passage for the family. Visits to the U.K. and other countries are contemplated from time to time.
This is a first-class opportunity for the right man to attain quickly high executive office in a particularly lively organisation.
Please apply in confidence to :—

Overseas Appointments Ltd.,
12, Grosvenor Place,
London, S.W.1

E8063 A

PRODUCTION MANAGER

required to DIRECT the production activities of a factory of some THOUSAND EMPLOYEES. The factory produces materials and components for the electronic industries and EXPERIENCE in the MASS PRODUCTION AND HANDLING OF SMALL PIECE PARTS by ADVANCED METHODS is essential. Familiarity with ceramic or metal powder processes would be an advantage.

SALARY £2,500 p.a.

Pension and Life Assurance

Applications in strictest confidence.—BOX No. E8060, " The Engineer."

A

RESEARCH OPPORTUNITIES

British Welding Research Association will shortly be appointing to the research staff at its Abington, Cambridge, laboratories, several ENGINEERS with either research experience or a strong leaning towards fundamental research and exceptionally well-qualified in the study of either **strength of materials** or **electrical technology**. There are also vacancies for **METALLURGISTS** and for **PHYSICISTS** with a strong leaning towards applied research. Selected candidates, who must possess appropriate honours degrees or possibly Ph.D.'s, will find a challenge to extend their own and the general field of knowledge of welding processes and welded structures combined with scope for increasing responsibility in a young and expanding organisation. The research programme covers a wide range of industry from heavy steel making to electronic components.

Candidates who feel that they are qualified to meet the above requirements, and that they could benefit from the exceptional opportunities for maintaining contact with industry, participating in the activities of the professional institutions, and for study of developments abroad, are invited to write for details of the research programme, or for an appointment to discuss their potential contributions.

The grades and salary ranges for the appointments are :

Principal Research Officers ...	£1350–£2250
Senior Research Officers ...	£1000–£1450
Research Officers	£650–£1150

Applications, with full particulars, to the Secretary, British Welding Research Association, Abington Hall, Cambridge.

E8072 A

We have been retained to assist in making the following appointments which will appeal to young engineers who have served an apprenticeship. Attained at least the Higher National Certificate in Electrical Engineering, and who are not content with narrow fields of interest.

ELECTRICAL ENGINEERS

Candidates must have experience in the DESIGN and APPLICATION of electrical equipment to industrial plant. The work involves drawing up semi-automatic schemes, including detailing of circuits, using a wide range of electrical machinery and control gear, as applied to the company's products in field closely related to mechanical handling.

ELECTRONICS ENGINEERS

Candidates must have had experience in the DESIGN of basic electronic equipment such as AC and DC Amplifiers, Oscillators, Bridge Networks and equipment using Transistors. Some knowledge of Servo Systems would be useful. The work involves the design and application of industrial electronic equipment such as servo systems, speed controls, timers, &c., and equipment using digital techniques to machinery in a field closely related to mechanical handling.

These posts are permanent and progressive in a rapidly expanding field. The company operates a contributory pension scheme and first class welfare services, and offers every encouragement for further education. Salary will depend on age and experience, but will be not less than £1000 p.a.

Applications will be treated in strict confidence, and should give the broadest possible picture of qualifications, &c., to :

H. JACKSON & PARTNERS, LTD.

Management Consultants

109, COLMORE ROW, BIRMINGHAM, 3

E7931 A

Classified Advts. continued on page 166

SITUATIONS VACANT

CHEMICAL ENGINEER FOR PRODUCTION MANAGEMENT

BROWN AND POLSON, LTD., Trafford Park, Manchester, 17,

require a Chemical Engineer with degree or equivalent qualification.

This is a good opportunity for a candidate having had experience involving unit operation. Candidates should be between 28-35, having had at least five years' management experience in process or chemical industries.

Good commencing salary, employee benefit schemes—promotional prospects are good.

Applications, in some detail, should be addressed to the Personnel Adviser.

E8010 A

SITUATIONS VACANT

ENGLISH ELECTRIC, RUGBY

require

CONTRACTS AND SALES ENGINEERS

Applicants, who should be aged between 26–32, must possess a minimum qualification of O.N.C. in Mechanical Engineering and have had at least 2 years' commercial experience, subsequent to an Engineering apprenticeship. Previous experience of Prime Movers would be advantageous, although not essential.

If you are interested in these vacancies, please write, giving full details (in confidence) of age, qualifications and experience, to Dept. C.P.S., Marconi House, 336/7, Strand, London, W.C.2, quoting reference E1197D.

E8001 A

SITUATIONS VACANT

ENGINEER

required to prepare operating and maintenance instructions for condensing and feed heating plants for power stations and marine closed feed systems. He would also be required to attend official tests, sea trials, and to be present during commissioning periods. This important appointment calls for sound technical training to at least Higher National Certificate level, adequate operating experience, and a good command of English. Successful applicant must possess initiative and the ability to work with the minimum of supervision.

Applications should be marked "Confidential" and addressed to The Technical Director, Worthington-Simpson, Ltd., P.O. Box 17, Newark, Notts.

E8026 A

SITUATIONS VACANT

GOVERNMENT SERVICE

ENGINEERING DRAUGHTSMEN

Government Communications Headquarters have vacancies at Cheltenham for MECHANICAL and ELECTRICAL DRAUGHTSMEN with design experience in any three of the following categories :—

Electronic equipment (rack mounted type, etc.)
Electrical work and small mechanisms.
Micro-wave equipment.
Fabricated parts, sheet metal work, outdoor structures.

Applicants should also have served a recognised engineering apprenticeship or have equivalent workshop knowledge, and preferably hold the Ordinary National Certificate.

There are opportunities for permanent and pensionable appointments and advancement to higher drawing office posts. Facilities given to study for National Certificates and other Courses in approved cases.

Three and a half weeks annual leave, plus all public and privilege holidays.

Write :
Personnel Officer,
G.C.H.Q. (D.O./15),
53, Clarence Street,
Cheltenham, Glos.

E7868 A

FORD

require a

PROCESS ILLUSTRATOR

for their

ASSEMBLY PLANNING SECTION

This unit provides perspective illustrations of body parts and assemblies showing sequence of manufacturing operations and methods of assembly.

The work is done entirely from a study of engineering blueprints and candidates in addition to being able to sketch should also have the ability to read and understand part prints.

A knowledge of motor body manufacturing and assembly conditions, methods and techniques would be an added advantage.

Applications to Mr. V. Williams, Training and Recruitment Department, Ford Motor Company Limited, Dagenham, Essex, quoting reference HPI.

E8025 A

Reed PAPER GROUP

THE REED PAPER GROUP

one of the leading paper-making and paper-converting companies in this country, is expanding its research activities in the fundamental technical problems of paper-making. A new unit is to be set up within Group Research and a few first-class scientists are required as Section Heads to direct research in the fields of classical physics, physical chemistry, hydro-mechanics, fibre technology and engineering.

There are no rigid qualifications for these positions, although a good Honours Degree and research experience will be required. Previous experience in paper-making is not essential. The successful applicants will be Scientists, aged approximately between 30 and 45, and of proven ability in research. Pay and prospects will be excellent, with the added stimulus of playing a leading role in the planning of an expanding enterprise. New laboratories are to be built near Maidstone in Kent.

Applications for these posts will be treated in strict confidence, and should be addressed to :

The Group Personnel Officer, Albert E. Reed & Co., Ltd., Larkfield, Nr. Maidstone, Kent.

quoting Ref. No. GR/SH/21.

E8012 A

NUCLEAR ENGINEERING

FOSTER WHEELER, LTD., REQUIRE

further staff for Research and Development Department

GRADUATE DESIGN ENGINEER

for work on novel projects connected with nuclear steam generating plant.

Preferred qualifications are a good Engineering Degree and some experience of the practical aspects of design and operation of high-pressure steam plant.

Commencing salary in the range : £850–£1100 per annum.

SENIOR INSTRUMENT ENGINEER

for work on novel projects connected with nuclear and conventional steam generating plant.

Responsibilities will include general instrumentation of test rigs, formulation of project instrumentation proposals and testing and evaluation of new instruments. Automatic control aspects will also be included. Degree or equivalent standard is desirable. Commencing salary in the range : £1050–£1400 per annum.

Applications, giving details of age, qualifications and experience, should be made in writing to :

Staff Manager,
Foster Wheeler, Limited,
3, Ixworth Place,
LONDON, S.W.3.

E8003 A

UNITED KINGDOM ATOMIC ENERGY AUTHORITY

announces the setting-up of a

CONSULTATION SERVICE

If you are an experienced scientist or engineer and think that you may be interested in a senior post (salary from £3000 upwards) with the United Kingdom Atomic Energy Authority, you can learn more about the opportunities available without committing yourself to making a formal application for a post.

Arrangements can be made for an

Informal and confidential interview

by telephoning or writing to Mr. H. S. Hoff, Personnel Consultant, U.K.A.E.A., 11, Charles II Street, London, S.W.1. (Whitehall 6262.)

The more relevant detail about yourself that you can supply in advance—qualifications, experience, age, &c.—the better.

The interview will be entirely confidential : after it no further action whatsoever will be taken by the Authority unless you specifically request it.

E8000 A

MUFULIRA COPPER MINES LIMITED

ENGINEERS

A large NORTHERN RHODESIA copper mine has vacancies for engineers. Applicants should preferably hold university degrees in mechanical or electrical engineering but men with other suitable qualifications or with extensive practical experience will also be considered.

There is a wide range of minimum basic commencing salaries from £1100 per annum for recent graduates to £1358 per annum for experienced men. Depending on ability and promotion, salaries considerably in excess of these minima are attainable. All grades participate in a Bonus Scheme (currently paying 36 per cent on basic salary) and a variable cost-of-living allowance (at present approximately £67 per annum) and in a generous Pension and Life Assurance Scheme.

Paid annual leave is at the rate of from 41 to 51 days per annum (depending on grade) and may be accumulated over three years' service. An excellent Medical Scheme, Share Purchase Plan and other employee benefits are available. Single or married accommodation, with basic furniture, is provided at nominal rental.

The climate is pleasant (the mine being situated at over 4000 feet altitude) and there are extensive sporting, recreational and excellent schooling facilities.

Applications, which should include full personal particulars and details of qualifications and experience, together with a recent photograph, to be forwarded to :—

The Mine Employment Department,
SELECTION TRUST LIMITED,
Mason's Avenue,
Coleman Street,
London, E.C.2.

PLEASE QUOTE R.26 "E."

E7946 A

SITUATIONS VACANT

SENIOR DRAUGHTSMEN

experienced in bulk mechanical handling or foundry work. Superannuation Scheme. Five-day week. Apply to MARCO CONVEYOR & ENGINEERING COMPANY Ltd., 42, George Road, Edgbaston. Birmingham, 15. Edgbaston 4980.

E8020 A

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Aged 23-33, with good drawing-office background, is required for the Chief Mechanical Engineer's office in Central London. A sound practical training and knowledge of engineering services is essential.

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Conditions of service include free lunches and an annual bonus, also a contributory pension scheme. Salary according to age, qualifications and experience.

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E8030 A

SITUATIONS VACANT

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Due to expanding business, a large electrical manufacturing firm in the Midlands requires assistant Design Engineers for rectifier work. Previous rectifier experience not necessary, but applicants should have Degree (Electrical) or equivalent, and some practical training. Work involves mercury arc and semi-conductor rectifiers and application engineering of all kinds, with scope for wide experience and interest ; good salary and prospects. Pleasant residential area ; ample housing ; educational facilities excellent.

Apply, with full particulars, to BOX No. E7853, " The Engineer."

A

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A vacancy exists for an Engineer to control and co-ordinate all mechanical aspects of semi-conductor device designs and manufacture.

Applicants with experience in Transistor, Diode, Valve or electro magnetic component manufacture are preferred, but experience in other fields of precision mechanical engineering will be given full consideration.

Salary will be commensurate with qualifications, experience and responsibilities undertaken. An attractive non-contributory pension scheme operates after initial probationary period.

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THE DIRECTOR OF ENGINEERING, NEWMARKET TRANSISTORS, LTD., EXNING ROAD, NEWMARKET

E8021 A

MSL *have been retained to advise on the appointment of a*

CIVIL ENGINEERING PLANT MANAGER

for a British firm of contractors. The company is expanding and operates widely overseas as well as in the U.K. He will manage depots and workshops in the London area employing over 200, and will control purchases exceeding £1 million p.a. in addition to being responsible for site maintenance of plant.

Starting salary between £2,250 and £2,750, according to experience : pension : car provided.

Candidates must have a thorough grasp of the economics of plant usage and of preventive maintenance derived from practical experience of maintaining a wide range of contractors' heavy plant. A qualification in mechanical engineering is desirable.

Please send brief details in confidence, quoting reference G.1914, to R. A. Denerley. In no circumstances will a candidate's identity be disclosed to our client unless he gives permission after a confidential interview at which he will be given full details of the appointment.

MANAGEMENT SELECTION LIMITED, 17, Stratton Street, London, W.1

E8009 A

ENGINEERING MANAGER FOR LARGE TIN BOX PLANT

Reckitt & Sons Limited wish to appoint a qualified and experienced ENGINEER to become within three years the overall Manager of an independent factory organisation employing about 900 people engaged in the design, printing and forming of tin boxes with facilities for other activities associated with the manufacture of containers, the moulding of plastics, &c.

The man appointed will immediately assume responsibility for supervising all the engineering activities in the factory including design and development, Tool Room and Machine Shop, together with associated departments.

The Company intends to keep abreast of new developments and is already committed to a programme for the improvement of processes and layout which it is ready to expand.

This is an important and senior appointment in a developing company with considerable resources and extensive interests both in this country and overseas.

Applications from men aged 35-45 years, should be addressed in writing to the Personnel Director, Reckitt & Sons Limited, Dansom Lane, Hull.

E8042 A

British Titan Products Co Ltd

have vacancies for

MECHANICAL ENGINEERS

at their Grimsby and Billingham Factories.

The Company is primarily concerned with the manufacture of Titanium Dioxide and is characterised by a tenfold expansion in post-war years. This continuing expansion offers plenty of scope for Engineers in the fields of Plant, Maintenance, Construction and Design. The current vacancies are for Maintenance and Construction work with opportunities later in the Design field.

Preference will be given to candidates with a University Degree in Mechanical Engineering, but those with an equivalent professional qualification will also be considered. Post-graduate apprenticeship is essential and the upper age limit for the appointments is 30.

Salaries and prospects are very attractive for men with the right qualifications. Annual bonus scheme and non-contributory endowment assurance and assistance for married men with house purchase and removal expenses.

Applications, in strictest confidence, to be addressed to the

Personnel Manager, British Titan Products Company, Limited, Billingham, Co. Durham, quoting reference S.4.

E160 A

ELECTRICAL ENGINEER

wanted by leading German manufacturer for German-English translations. Applications are invited from British-trained engineers with a good general education and sound technical training, preferably also with practical experience in the application of electric equipment. Good working knowledge of German is essential. The ability to write clearly and concisely will be expected of candidates. A five-day week is worked with generous holidays. Favourable housing conditions for permanent staff.—Apply, stating age, education, qualifications, experience and salary required. —BOX No. E8059, " The Engineer."

A

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CASTINGS.—We can save your porous castings, ferrous or non-ferrous, by an approved impregnation process ; sample castings treated ; A.I.D. approved. —Recupero, Ltd., 66, South Harrow Viaduct, Harrow, Middlesex ('Phone, Byron 1178). E109 MW

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BELLMANS MASTS FOR HIRE, to lift from 1 to 20 tons, 30ft. to 150ft. Blocks and tackle. Hand-operated winches. From £1 per day.—BELLMAN'S (Phone : SLOane 5259), Hobart House, Grosvenor Place, S.W.1. E103 K

Classified Advts, continued on page 168

BUSINESS OPPORTUNITIES

REMPLOY SPONSORSHIP SCHEME.—Send for details which show an attractive proposition to manufacturers.—Write to the Managing Director, Remploy, Ltd., 25–28, Buckingham Gate, S.W.1, or telephone VICtoria 6621 (12 lines). E155 G

INVENTORS AND IDEAS MERCHANTS PLEASE NOTE. Production Engineering Company with modern sheet and strip factories, and world-wide sales organisation, propose to expand range of products. Suggestions invited, for suitable lines. Valid patents would be bought or worked. Accepted suggestions paid for, &c.—BOX No. E2630, "The Engineer." G

DIRECTORSHIP AND HALF PROFITS of growing light Engineering Company (Ltd.), East Sussex coast, with valuable contacts, offered to working Engineer by retiring Director. About £3000 necessary.—BOX No. E2643, "The Engineer." G

WOULD £5000 HELP YOU TO GET AHEAD?

£5000 is the main prize in the new Get Ahead contest organised by the *News Chronicle*. The B.B.C. will televise eight heats and the final. You need not have your own business to qualify for the final. All finalists will win considerably more than £200. In all, £7500 will be won. Anyone with a sound business idea for putting £5000 to good use should write for details *now* to: Get Ahead, *News Chronicle*, 4/7, Lombard Lane, London, E.C.4.

E7991 G

PATENTS

THE PROPRIETOR of British Patent No. 737771 entitled "A MACHINE FOR OPERATING ON STRIP STOCK AND A RECIPROCATING SLIDE FEED THEREFOR," offers same for license or otherwise to ensure its practical working in Great Britain.—Inquiries to Singer, Stern and Carlberg, Chrysler Building, New York 17, New York, U.S.A. E7961 H

THE PROPRIETOR of British Patent No. 678,639 for "SEWING MACHINE AND MEANS FOR AUTOMATICALLY PRODUCING RECURRING OPERATIONS," desires to enter into negotiations with a firm or firms for the sale of the patent or for the grant of licences thereunder.—Further particulars may be obtained from Marks & Clerk, 57 and 58, Lincoln's Inn Fields, London, W.C.2. E8038 H

THE PROPRIETOR of British Patent No. 715619, entitled "METAL WORKING MACHINES AND OPTICAL PROJECTION APPARATUS THEREFOR," offers same for License or otherwise to ensure practical working in Great Britain.—Enquiries to Singer, Stern and Carlberg, 14, E. Jackson Blvd., Chicago 4, Illinois, U.S.A. E8054 H

MISCELLANEOUS

MOBILE LIFTING SERVICES.—Lump sum or Hire Rate Quoted for any Lifting Work by Lorry-Mounted or Crawler Cranes, any size, any area.—TARSLAG, LTD., Rotherham, 3235. E166 I

MACHINERY Etc. WANTED

URGENTLY REQUIRED

ONE NO. 120 ZENITH PILE EXTRACTOR Suitable for use on No. 4 Frodingham Piling. Further details.—BOX No. E7993, "The Engineer." F

WANTED.—450/500kW Alternator, speed 333 r.p.m., wound for 400/440 volts, 3-phase, 50 cycles.—BOX No. E8005, "The Engineer." F

ELECTRIC MOTOR. 150/250 h.p., 428 r.p.m., for direct coupling. Squirrel cage, 400/440 volts, 3-phase, 50 cycles.—BOX No. E8058, "The Engineer." F

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E7988 G

BLISS 1000-TON POWER PRESS, MODEL 80½, single crank, single action, straight sided, stroke 20in., bed 47in. by 60½in., speed 5 strokes per minute, 60 h.p. motor drive with mechanical friction clutch.—Thos. W. Ward, Ltd., Albion Works, Sheffield. 'Phone: 26311. Ext. 371. E8018 G

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600

DIESEL ENGINE DRIVEN ALTERNATOR SETS

500kW continuous 400V., 3-phase, 50 cycles, 4-wire BELLISS AND MORCOM/LANCASHIRE DYNAMO COMPANY Diesel Engine Driven Alternator Set, direct coupled at 375 r.p.m. and comprising 7-cylinder vertical engine complete with ancillaries and starting equipment. Direct coupled to alternator with switchgear.

Six 330kVA, 400/440V, 3-phase, 50 cycles, 4-wire self-contained RUSTON PAXMAN type 12RPH2/B.T.H. Diesel Engine Driven Alternator Sets, radiator fan cooled. Each on bedplate and direct coupled at 1000 r.p.m.; electric starting; standard ancillaries and switchgear.

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NEALS "QMC" 4-6-ton Crawler, 50ft. Jib, 1949, thoroughly overhauled 6 months. £1350.
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ANDERSON 5-ton Electric Derrick Crane, 120ft. Jib, New 1946. £2600.
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ANDERSON 10-ton Electric Derrick, 120ft. Jib, 1945, good condition. £3450.
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E8004 G

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OVERHEAD CRANES.—30/5-ton Adamson 42ft. 3in. span, 400/3/50; 20/6-ton Vaughan 42ft. 3in. span, cab type (6); 20-ton King, 42ft. 3in. span, 400/3/50; 15-ton Morris, 35ft. span, hand-operated; 10-ton Morris, 45ft. span, 36ft. lift; 10-ton Morris "Goliath," 40ft. span, 400/3/50; 10-ton Vaughan, 23ft. 6in. span, 400/3/50; 10-ton Vaughan, 21ft. span, 44ft., lift, 7½tons; Wharton, 25ft. span, 400/3/50; 5-ton Henderson, 24ft. 7in. span, 1946; 5-ton Morris, 58ft. span, hand-operated; 5-ton Royce, 2-motor crab, 440/3/50; 5-ton King, 29ft. 3in. span, power hoist, hand travel; 5-ton Morris, 28ft. 6in. span, power hoist, hand travel; 4-ton Morris, 19ft. span, 220V, d.c. (3); 3-ton Adamson, 48ft. span, 400/3/50; 2-ton Adamson, 34ft. span, 400/3/50 (2); 2-ton Morris, 18ft. span; 2-ton Vaughan, 27ft. 6 in. span, 2-motor; majority of the above are unused.

DERRICK CRANES.—7-ton Rushworth, hand, 30ft. jib; 5-ton Wilson, electric, 70ft. jib; 1½-ton Anderson Grice, hand, 40ft. jib.

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LOCOS.—Fowler diesel, 150 h.p. (2); Bagnall 14in. by 22in. (two oil-fired, one coal), Peckett, steam 7in. by 12in., 1941; also 3 miles track, 24in. gauge, Bogies, Turnouts, &c.

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SLING ENGINEERING WORKS
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'Phone: Coleford 2271/2. E106 G

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Edwards

SCHULER Power Geared Open Fronted, Inclinable, Cam Action, Double Action Drawing Press with adjustable bed. Spring balanced blankholder. With automatic ejector and vertical adjustment, punch stroke 11in., blankholder stroke 4½in., bed 24½in. by 14½in.

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NEW STOELTING Pyramid Type Plate Bending Roller, motorised 400/440/3/50, capacity 10ft. wide by ½in. mild steel, diameter of rollers, top, 9½in., bottom, 7½in., drop-end bearing for removal of completed cylinders, support rollers to bottom rolls, reduction gearbox drive to bottom rolls, with multi-disc slipping clutches, motorised adjustment to top roller.

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STEAM ALTERNATOR SETS

Two 1000kW, 3·3kV, 3-phase, 50 cycles, back pressure type Steam Turbo Alternator Sets, each incorporating turbine by BELLISS AND MORCOM. Speed 4500 r.p.m.; steam pressure 195 p.s.i.g., 380 deg. Fah. temp., exhausting against 15 lb back pressure. Direct coupled through David Brown gearbox to alternator by HARLAND ENGINEERING COMPANY, with direct coupled exciter. Switchgear with automatic voltage regulator. Also with hand-operated overhead crane.

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One 350kW, 400/440V, 3-phase, 50 cycles, Steam Engine Driven Alternator Set incorporating compound engine by BELLISS AND MORCOM, having h.p. cylinder 18in. bore, l.p. cylinder 26in. bore by 11½in. stroke. Developing 500 h.p. when running at 375 r.p.m. and when supplied with steam at 150 p.s.i. exhausting to back pressures up to 20 lb. Direct coupled to alternator by ENGLISH ELECTRIC, having overhung exciter. Complete with switchgear.

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December 15	Miscellaneous stores.	General Stores Sub-Depot, Longtown, Nr. Carlisle. (Sale at County Hall, Carlisle.)	HARRISON & HETHERINGTON (Dept. L), Botchergate, Carlisle. (Tel.: 26292.)
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1960 January 4-8	Machine tools and miscellaneous stores.	M.O.A. Storage Depot, Royal Arsenal, Woolwich, London, S.E.18.	FULLER, HORSEY, SONS & CASSELL (Dept. L), 10, Lloyd's Avenue, London, E.C.3. (Tel.: Royal 4861.)

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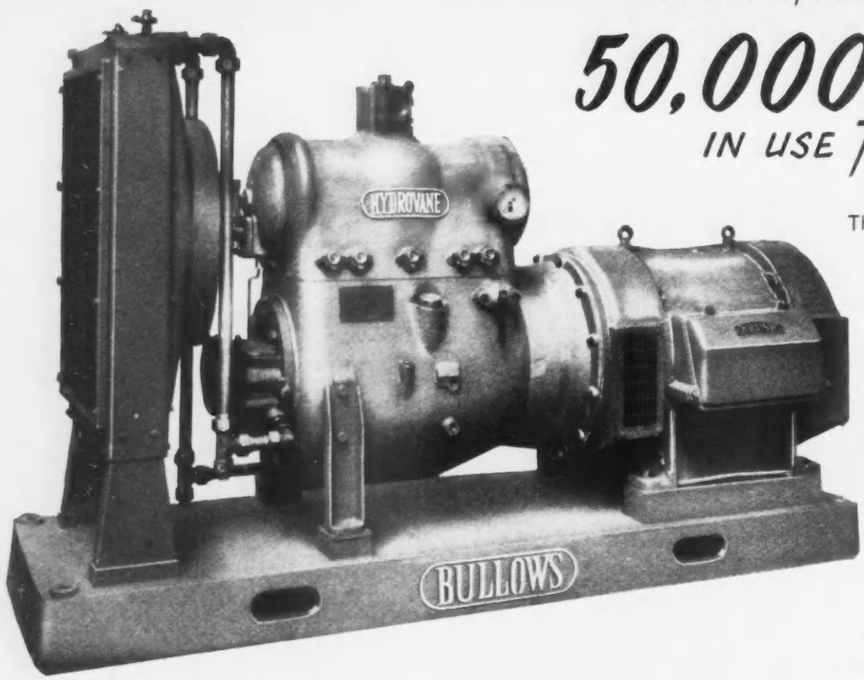

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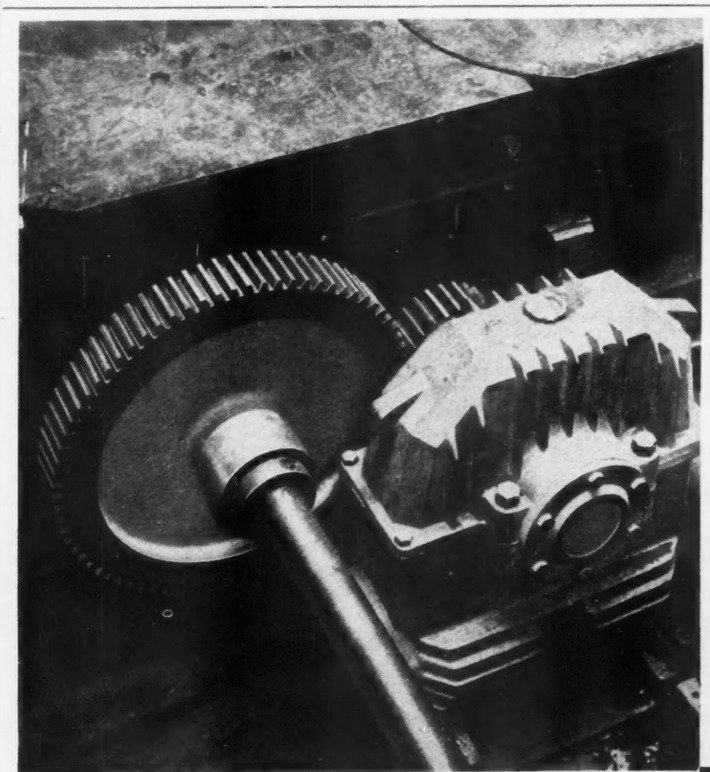

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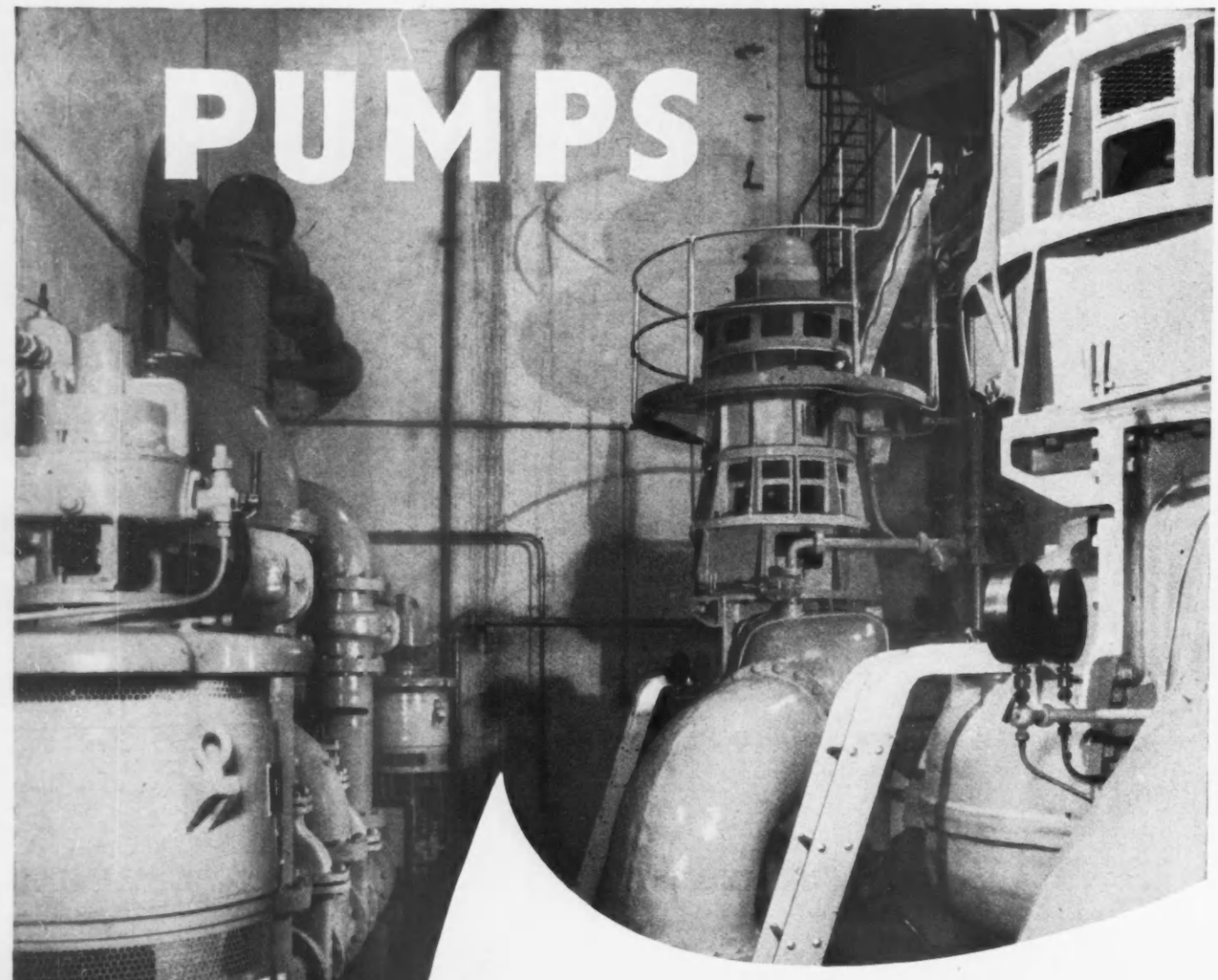

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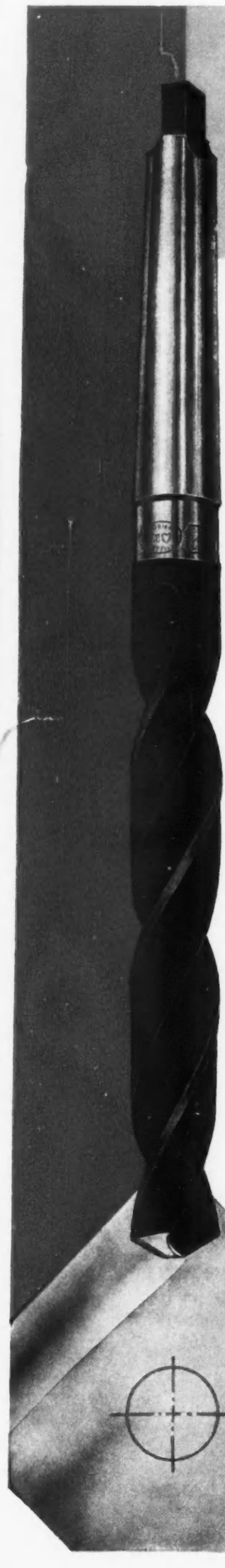

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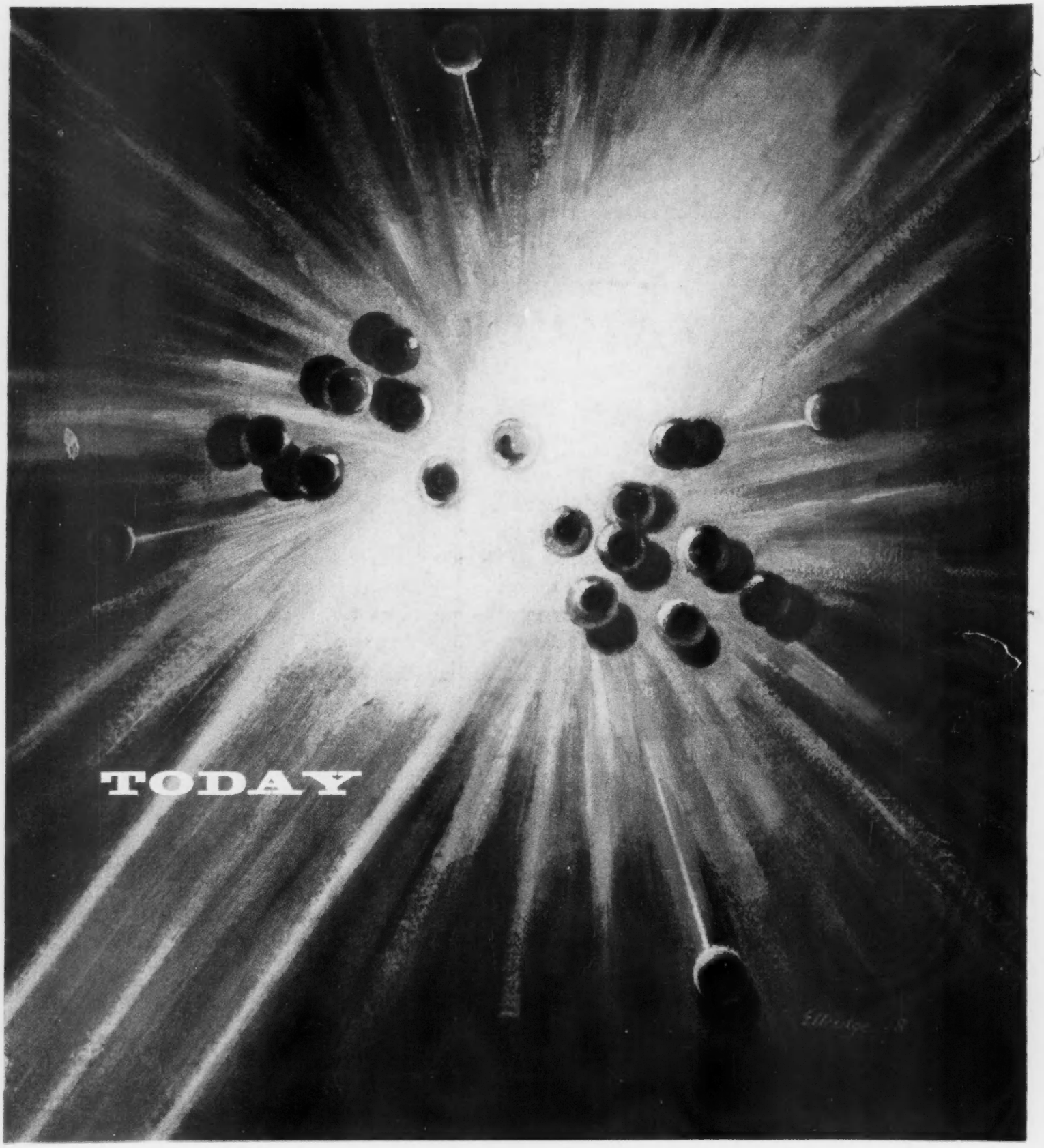

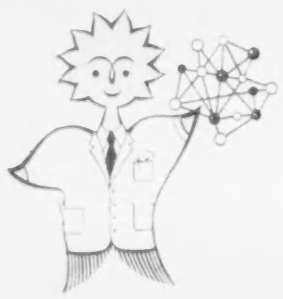

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